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TREATABILITY STUDY REPORT
AND
PROCESS FORMULATION REPORT

FOR

ADMIN RECORD

POND SLUDGE AND CLARIFIER

TEXT
APPENDIX A AND B
VOLUME 1 OF 3

REVISION 0

HALLIBURTON NUS CORPORATION

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TREATABILITY STUDY REPORT
AND
PROCESS FORMULATION REPORT

FOR

POND SLUDGE AND CLARIFIER

REVISION 0

PREPARED FOR
EG&G ROCKY FLATS
GOLDEN, COLORADO

PREPARED BY:
HALLIBURTON NUS CORPORATION
PITTSBURGH, PENNSYLVANIA

JUNE, 1995

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LIST OF ACRONYMS AND ABBREVIATIONS

Am	Americium
ASTM	American Society for Testing and Materials
$Ca(OH)_2$	Calcium Hydroxide (Hydrated Lime)
CaO	Calcium Oxide (Quick Lime)
CAMUs	Corrective Action Management Units
COC	Constituents of Concern
CDR	Conceptual Design Report
Cs	Cesium
CSS	Chemical Stabilization/Solidification
cy	Cubic Yard
D&D	Decontamination and Decommissioning
DOE	Department of Energy
g/cc	Grams per Cubic Centimeter
HDPE	High-Density Polyethylene
HEPA	High Efficiency Particulate Air (Filter)
HNUS	Halliburton NUS
IM/IRA	Interim Measure/Interim Remedial Action
LDR	Land Disposal Restrictions
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
MSDS	Material Safety Data Sheet
MTRs	Minimum Technology Requirements
NTS	Nevada Test Site
OU4	Operable Unit 4
pCi/L	Pico-curies per Liter
POC	Point of Compliance
PS	Performance Standards
psi	Pounds per Square Inch
Pu	Plutonium
Ra	Radium
RFETS	Rocky Flats Environmental Technology Site
RPM	Revolutions Per Minute
SEP	Solar Evaporation Ponds
SG	Specific Gravity
SU	Standard Units
TCLP	Toxicity Characteristic Leaching Procedure

TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TUs	Temporary Units
U	Uranium
UCS	Unconfined Compressive Strength
USEPA	United States Environmental Protection Agency
WAC	Waste Acceptance Criteria
W/P	Water-to-Pozzolan

EXECUTIVE SUMMARY

This report constitutes the Treatability Study Report and Process Formulation Report for Pond Sludge. It has been prepared by Halliburton NUS Corporation (HNUS) as part of the EG&G Subcontract MTS 225471AS, Task Order 353010ST3. The purpose of this report is to summarize the treatability study work conducted at the HNUS Laboratory in Pittsburgh, Pennsylvania. This report provides supporting documentation for all treatment-related Waste Acceptance Criteria (WAC) required for ultimate waste disposal into the Operable Unit 4 (OU4) closure at the Rocky Flats Environmental Technology Site in Golden, Colorado.

The Rocky Flats Environmental Technology Site (RFETS) is located in northern Jefferson County, Colorado. The RFETS is a government-owned, contractor-operated facility whose former mission was producing component parts for nuclear weapons. Key production activities involved the fabrication of parts from plutonium, uranium, and nonradioactive metals. The site's current mission is focused on environmental restoration, waste management, and decontamination and decommissioning of facilities.

The scope of this treatability study encompasses the wastes associated with Operable Unit 4 (OU4). The Solar Evaporation Ponds located at RFETS, is an element of the U.S. Department of Energy (DOE) Environmental Restoration Program at the site. OU4 includes the five solar evaporation ponds designated 207A, 207B (north, center, and south), and 207C. The contents of the Building 788 clarifier will also be included in the OU4 closure.

The sludges from Solar Evaporation Ponds 207A, 207B (series), and 207C have been removed and placed into approximately 82 tanks located on the 750 Pad. Each tank has a nominal 10,000-gallon capacity and is constructed of high-density polyethylene (HDPE). The Building 788 Clarifier contains approximately 10,000 gallons of sludge. This material originated from Pond 207A during the original pondcrete solidification project.

As part of the closure plans for OU4, the sludges are to be treated and then placed in the OU4 closure area and covered with an engineered cap. Specific Waste Acceptance Criteria (WAC) and Performance Standards (PS) have been established for disposal of pond and clarifier sludges within the OU4 closure. The WAC and PS which must be met are as follows:

- The treatment shall be the minimum needed to meet all WAC and PS.

- The treated waste shall not, prior to placement, contain free liquids as determined by the Paint Filter Liquids Test, Method 9095 (SW 1992).

- The treated waste can be delivered as a monolith or in particulate form. If a monolith:

    - Shall fit within a rectilinear envelope 12 inches x 24 inches x 48 inches
    - Shall not exceed 3,000 pounds per square inch (psi) compressive strength
    - Shear and tensile strengths shall not exceed those of 3,000-psi concrete
    - Shall not be delivered in molds, containers, or packaging that cannot be returned

    If in a particulate form:

    - Shall pass a 3-inch screen
    - Shall not agglomerate into particles greater than 3 inches during storage. If agglomeration does occur, the material shall meet all the criteria specified for a monolith, listed above.

- When treated waste is mixed with site soils, no agglomeration greater than 3 inches shall occur.

- Treated waste shall be resistant to dispersion by wind.

- During storage, treated waste shall not produce dust or dispersible fines and will not degrade upon wetting.

- Treatment additives shall not cause the proposed remedy to fail to be protective of human health and the environment.

- Pathogens shall be removed or rendered innocuous.

- Treated waste shall not produce gas at a rate or volume greater than that produced by natural site soil.

- Total treated waste volume shall be less than 20,000 cubic yards (cy).

- Leachate shall not contain constituents at concentrations that, when modeled, are not protective of human health and the environment.

Baseline analysis of the pond sludges were performed at the start of the treatability study. TCLP leachate data were compared to preliminary modeling data to assess the potential impact of the disposal of untreated pond sludges in the OU4 closure. The information shows that some of these sludges would eventually leach cadmium from the OU4 closure at levels that are not protective of human health, based on current OU4 closure design conditions. This indicates that treatment of these sludges is required due to the leachability of cadmium.

The general concept used for developing process formulations for the stabilization of pond sludge followed a progression from performing initial analysis and testing of the raw waste, to screening various additives through a more comprehensive evaluation of additive formulations. Then, finally, the selected candidate formulations that passed all of the previous evaluation criteria were subjected to final WAC compliance testing. A major objective of the treatability study was to develop data showing compliance with the WAC over a wide operating range for key process parameters. The most important parameters were the waste loading, measured as percent total solids of the sludge, and the water-to-pozzolan ratio, which control the amount of pozzolan (defined as cement plus fly ash) required for effective treatment. The amount of lime required to raise the pH of the pond and clarifier sludges for disinfection and to reduce the leachability of metals and radionuclides was also a key parameter.

The treatability study evaluated numerous additives, singularly and in combination, including cement, fly ash, lime, and silica flour. Once it was determined that a specified formulation resulted in an acceptable end product, testing was conducted to develop an operating envelope that could be used during remediation. The operating envelope was developed to be conservative enough to ensure that all samples passed the required criteria.

Based on the treatability testing, several parameters appear to be the most significant regarding process control. These include the pozzolanic mixture composition, the ratio of water to pozzolans in the process stream, and the solids/moisture content of the waste.

A treatment system consisting of the addition of hydrated lime, Type C fly ash, and Type I/II Portland cement is recommended for treating the waste materials. The hydrated lime is necessary to raise the pH to greater than 12 to stabilize the sludge and inhibit gas generation via biological decomposition of the organics in the waste, as well as to reduce the leachability of most metals and radionuclides. The cement and fly ash are required to eliminate the free water in the waste, achieve the WAC requirement for disposal in the OU4 closure, and to aid in the production of a friable product. All WAC, with the exception of total volume of treated waste (which includes treated pondcrete) and the leachate concentration for sodium, were satisfied with the selected lime/fly ash/ cement treatment system.

The selected formulation for lime/fly ash/cement is the same system investigated in 1992 for the production of monoliths for offsite disposal (HNUS 1992b) and (HNUS 1992c). The current treatability study for the production of a friable product, as well as the previous treatability study, both selected ratios of fly ash/cement of 2/1 as the desired operating ratio.

The process operating ranges of key parameters for treatment of pond and clarifier sludges is as follows:

- <u>208 A/B Sludge</u>
  - Waste loading total solids: .... 10% to 30%
  - Water-to-pozzolan ratio tested that met WAC: .... 0.20 to 0.30
  - Water-to-pozzolan ratio that produces a friable product: ... 0.22 to 0.27
  - Lime addition by weight of waste feed: .... 7.5% ± 2.5%

- <u>207C Waste</u>
  - Waste loading total solids: .... 56.3% to 82.5%
  - Water-to-pozzolan ratio tested that met WAC: .... 0.15 to 0.35
  - Water-to-pozzolan ratio that produces a friable product: ... 0.18 to 0.26
  - Lime addition by weight of waste feed: .... 7.5% ± 2.5%

- <u>Clarifier Sludge</u>
  - Waste loading total solids: .... 20% to 38.1%
  - Water-to-pozzolan ratio tested that met WAC: .... 0.20 to 0.30
  - Water-to-pozzolan ratio that produces a friable product: ... 0.22 to 0.27
  - Lime addition by weight of waste feed: .... 7.5% ± 2.5%

- <u>Combined 207C/Clarifier Sludge</u>
  - Waste loading total solids: .... 49% to 73.6%
  - Water-to-pozzolan ratio tested that met WAC: .... 0.16 to 0.30
  - Water-to-pozzolan ratio that produces a friable product: ... 0.18 to 0.26
  - Lime addition by weight of waste feed: .... 7.5% ± 2.5%

1.0 PROJECT DESCRIPTION

1.1 AUTHORIZATION

This report has been prepared by Halliburton NUS Corporation (HNUS) as part of the EG&G Subcontract MTS 225471AS, Task Order 353010ST3. The purpose of this report is to summarize the treatability study work conducted at the HNUS Laboratory in Pittsburgh, Pennsylvania. This report provides supporting documentation for compliance with all treatment-related Waste Acceptance Criteria (WAC) required for ultimate waste disposal into the Operable Unit 4 (OU4) closure at the Rocky Flats Environmental Technology Site (RFETS) in Golden, Colorado.

This report constitutes the Treatability Study Report and Process Formulation Report for Pond Sludge. Included as appendices are the Equipment Recommendation Report and Modeling Report (Appendices A and B, respectively).

1.2 SITE DESCRIPTION

The RFETS is located in northern Jefferson County, Colorado. The site is currently managed by EG&G Rocky Flats, Inc., for the United States Department of Energy (DOE). The plant consists of 6,550 acres of Federal land, bounded by Colorado Highways 93 and 128 on the west and north, respectively; Indiana Street on the east; and Colorado Highway 72 on the south (Figure 1-1). The plant structures are centrally located within the site inside a security fenced area of about 384 acres as shown in Figure 1-2.

1.2.1 Rocky Flats Plant Background

The RFETS is a government-owned, contractor-operated facility whose former mission was producing component parts for nuclear weapons. Key production activities involved the fabrication of parts from plutonium, uranium, and nonradioactive metals, principally beryllium, stainless steel, and aluminum. Components made at the RFETS were shipped elsewhere for final assembly. The site began operations in 1952 in 20 buildings and grew continually to more than 100 buildings. In 1989 production operations were halted at the RFETS.

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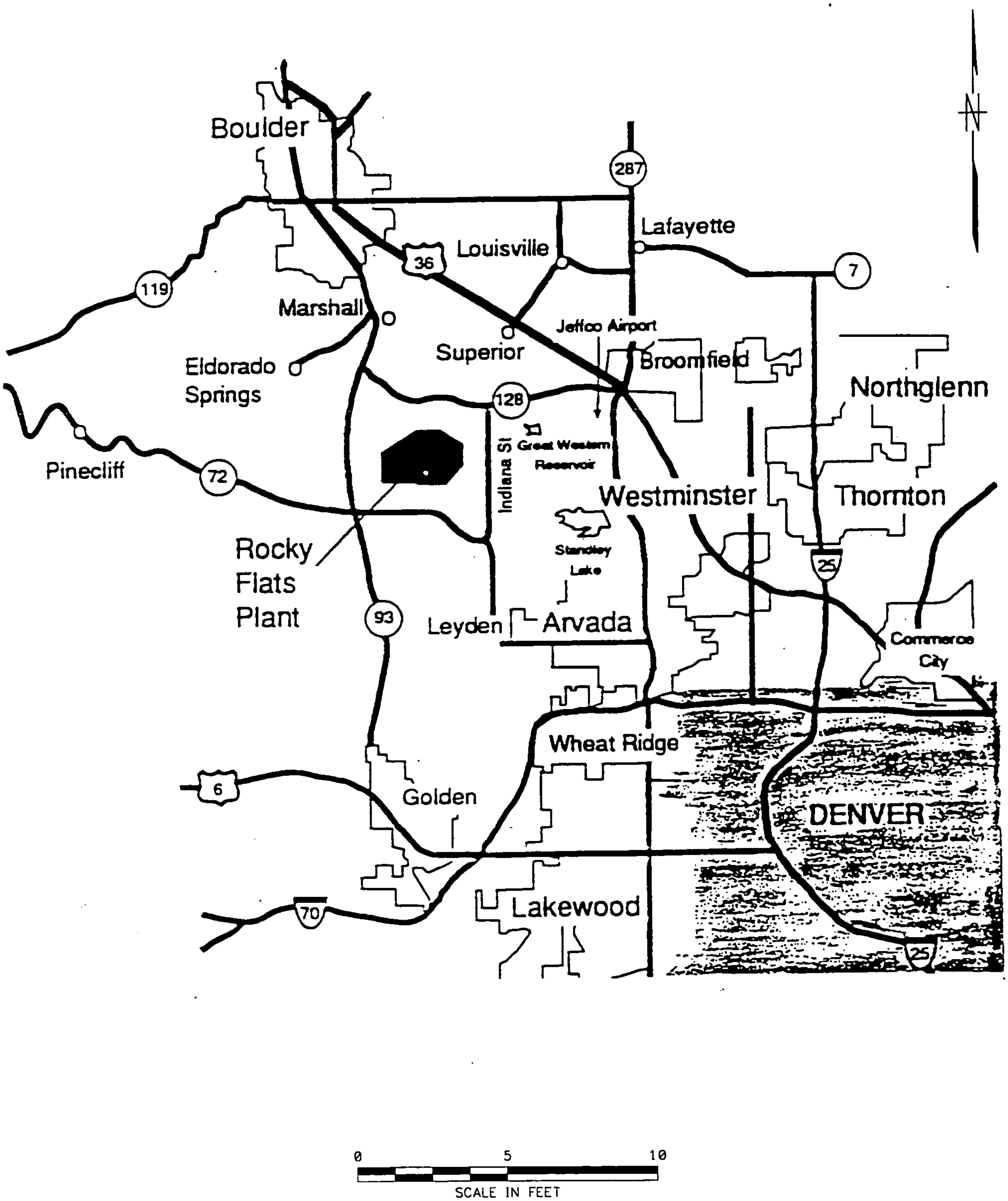

AREA MAP OF RFETS AND
SURROUNDING COMMUNITY
GOLDEN, COLORADO

FIGURE 1-1

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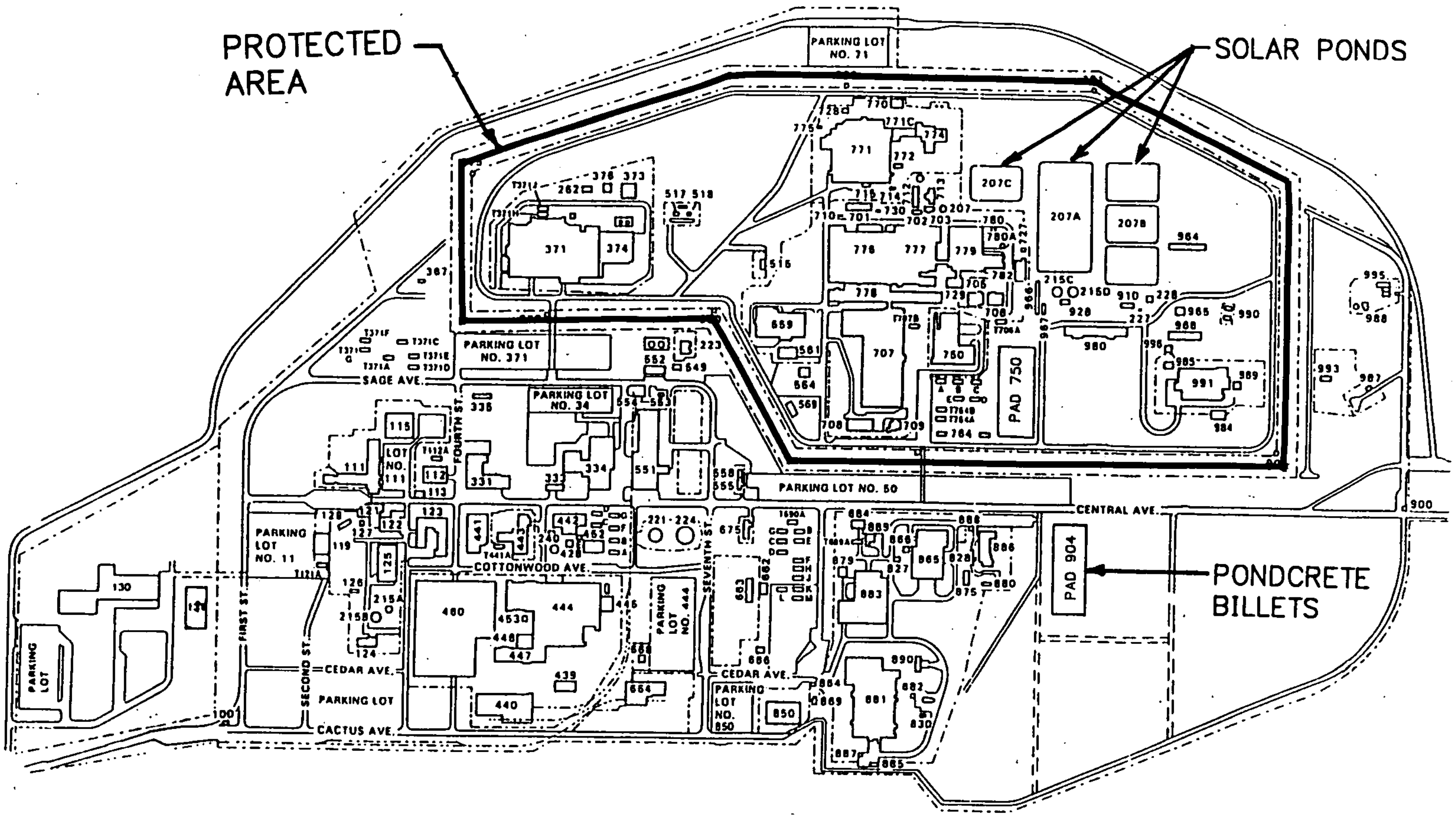

FIGURE 1-2

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Halliburton NUS CORPORATION

The plant's historical production mission was officially discontinued in 1992 with the end of the Cold War and the administration's decision not to resume weapons component production activities at the RFETS. Subsequently, EG&G formed a Transition Management organization to help the RFETS undertake a new mission focusing on environmental restoration, waste management, decontamination and decommissioning (D&D) of facilities, and economic development. The activities at the RFETS are currently continuing in these areas.

1.2.2 Operable Unit 4 Description

Operable Unit 4 (OU4), the Solar Evaporation Ponds, is an element of the DOE Environmental Restoration Program at the RFETS. OU4 includes the five solar evaporation ponds designated 207A, 207B (north, center, and south), and 207C. The contents of the Building 788 clarifier will also be included in the OU4 closure.

During construction of the Rocky Flats Plant in the early 1950s, a clay-lined solar evaporation pond was installed. The pond was designed for the impoundment of aqueous waste products discharged from the Process Waste Treatment Plant. The waste contained high levels of chemical contaminants, such as fluorides, nitrates, and various metallic ions. As a result of the changing plant operations and environmental requirements, additional evaporation ponds were constructed. On occasion these ponds were used for the disposal of untreated waste products, such as metallic lithium, acids, sewage sludge, plating residues, and several other wastes associated with operations at the RFETS (Wienand & Howard, 1992).

In efforts to remediate the ponds, the sludges from Solar Evaporation Ponds 207A, 207B (series), and 207C have been removed and placed into approximately 82 tanks located on the 750 Pad. Each tank has a nominal 10,000-gallon capacity and is constructed of high-density polyethylene (HDPE). The removal of the Building 788 Clarifier sludge is currently scheduled for the Spring of 1995. The Building 788 Clarifier contains approximately 10,000 gallons of sludge. This material originated from Pond 207A during the original pondcrete solidification project. As part of the closure plans for OU4, the sludges are to be treated to satisfy specific Waste Acceptance Criteria (WAC) requirements and then placed in the OU4 closure area and covered with an engineered cap.

1.3 WASTE DESCRIPTION

The wastes contained in the ponds and clarifier at the RFETS are classified as low-level mixed waste. United States Environmental Protection Agency (USEPA) Hazardous Waste Numbers associated with the pond wastes and clarifier sludge are F001, F002, F003, F005, F006, F007, F009, and D006.

Waste characterization studies (Weston 1991) and (HNUS, 1992a) were conducted in 1991 and 1992 to determine the physical and chemical composition of the solar pond and clarifier waste. The following provides a brief description of the waste types.

1.3.1 Ponds 207A and 207B (North, Center, and South)

Pond 207A was placed into service in 1956 and is currently lined with asphaltic concrete. The pond was cleaned out in 1985. The remaining liquid and sediment in the pond are the result of precipitation and wind blown residue from adjacent areas.

Ponds 207B north, center, and south were put into service in 1960. All are currently lined with asphaltic concrete with the exception of 207B south, which is lined with synthetic Hypalon. These ponds were cleaned out in 1977. The original pond liners and pond sludge were disposed of during this cleanout. After 1977, the ponds held treated sanitary effluent resulting from start-up and testing of a reverse osmosis plant that had been proposed for treatment of sanitary sewage effluent. Also, Pond 207B north was previously a receptor for contaminated groundwater from the nearby underlying french drain collection system (Wienand and Howard, 1992).

Sampling of the ponds was conducted in 1991 to support treatment and offsite disposal of the pond sludges. The analytical program was selected based on the USEPA hazardous waste codes and Land Disposal Restrictions (LDR) standards associated with the pond materials. Also, geotechnical, physical, and radiochemical parameters were evaluated.

Approximately 220,000 gallons of sludges from Ponds 207A and 207B (series) have been combined and are stored in HDPE tanks on the 750 Pad. Water has been decanted from the tanks and the remaining sludges are estimated to be between 10 and 30 percent solids. Characterization data for the pond sludges reveal an organic content, measured as Total Organic Carbon (TOC) ranging from 3,200 mg/kg to 14,000 mg/kg. The pH of the ponds varied between 8.3 and 9.0. Metals of concern in the sludges include barium, cadmium, arsenic, chromium, and nickel. Baseline characterization data of the sample of combined 207 A/B sludge used for this treatability study can be found in Section 3.1.1.

Comparing 1991 characterization data for individual pond sludges with current regulations, Ponds 207A, 207B north, and 207B center sludge samples exceed the LDR standard for cadmium. No other standards for the 207A and 207B (series) pond sludges are exceeded.

The 1991 characterization was completed to evaluate the waste according to LDR standards and to support the process of offsite disposal of the treated product. Currently, the plan is to place the treated waste within the OU4 closure area. This treatment and subsequent placement will take place under the Corrective Action Management Units (CAMUs) regulations, as promulgated by U.S. EPA (USEPA 40 CFR 264) and (USEPA 40 CFR 265), and the State of Colorado (Colorado 6 CCR 1007-3). These regulations allow remediation wastes to be consolidated or processed without triggering LDRs or Minimum Technology Requirements (MTRs), which were promulgated to control hazardous waste production from ongoing manufacturing activities. It is anticipated that treatment process trains will probably be permitted under RCRA Subpart X rather than Temporary Unit (TU) regulations.

The current plan to dispose of the pond sludges within the OU4 closure area must prove to be protective of both human health and the environment and must meet the WAC requirements and Performance Standards. Protection of human health must be demonstrated by computer modeling. The computer model predicts which contaminants have a potential to migrate from the waste area and potentially affect human health. These contaminants have been evaluated in the treatability study.

1.3.2 Pond 207C

Pond 207C was placed into service in 1970 and is lined with asphaltic concrete. Pond 207C waste contains high amounts of nitrate and other salts. The wastes in Pond 207C had three distinct layers; a brine phase, a crystalline phase, and a silty sludge phase. The brine layer was stratified, with higher dissolved solids concentrations at the bottom of the brine layer. Below the aqueous layer was a solid crust containing salt crystals. Beneath the crystalline phase was a layer containing silty sludge.

Approximately 413,000 gallons of material (brine, crystal, and silty sludge) from Pond 207C have been combined and are stored in HDPE tanks on the 750 Pad. The material has a specific gravity of 1.5 to 2.0. The pH of the 207C material, which is approximately 10.2, is the highest of all the ponds. The characterization showed that, in general, the concentrations of inorganics in both the brine phase and sludge were significantly higher than in the other ponds. Specifically, arsenic, cadmium, chromium, nickel, and silver were detected at higher concentrations. The brine phase contains percent level concentrations of nitrates, chlorides, and sulfates. Total salt content, as indicated by Total Dissolved Solids (TDS), has been measured as high as 35 percent in the brine phase.

Comparing 1991 characterization data with current regulations, Ponds 207C aqueous samples exceeded LDR standards for cyanide (total) and chromium. In addition, sludge samples contained concentrations of cadmium and chromium that exceeded LDR standards.

The 1991 characterization was completed to evaluate the waste according to LDR standards and to support the process of offsite disposal of the treated product. Currently, the plan is to place the treated waste within the OU4 closure area. This treatment and subsequent placement will take place under the Corrective Action Management Units (CAMUs) regulations, as promulgated by U.S. EPA (USEPA 40 CFR 264) and (USEPA 40 CFR 265), and the State of Colorado (Colorado 6 CCR 1007-3). These regulations allow remediation wastes to be consolidated or processed without triggering LDRs or Minimum Technology Requirements (MTRs), which were promulgated to control hazardous waste production from ongoing manufacturing activities. It is anticipated that treatment process trains will probably be permitted under RCRA Subpart X rather than Temporary Unit (TU) regulations.

The current plan to dispose of the pond sludges within the OU4 closure area must prove to be protective of human health and the environment and must meet the WAC requirements and Performance Standards. Protection of human health must be demonstrated by computer modeling. The computer model predicts which contaminants have a potential to migrate from the waste area and potentially affect human health. These contaminants have been evaluated in the treatability study.

1.3.3 Building 788 Clarifier

The Building 788 clarifier is located between Ponds 207A and 207C. The clarifier has a capacity of approximately 25,000 gallons, and was used to thicken Pond 207A material during the original pondcrete solidification project in 1985. The clarifier currently contains approximately 10,000 gallons of sludge.

The sludge in the clarifier contains approximately 39 percent solids. When the clarifier sludge is transferred to storage tanks on the 750 Pad, the solids content will be reduced by dilution water added to help in the removal of the sludge.

The clarifier sludge contained relatively higher concentrations of metals than the pond sludges. Barium, cadmium, chromium, lead, and nickel were of particular concern. Low levels of volatile organics, including tetrachloroethene, were detected in the sludge.

Comparing 1991 characterization data to current standards, the clarifier sludge exceeds the current LDR criteria for cadmium, nickel, and tetrachloroethene.

The 1991 characterization was completed to evaluate the waste according to LDR standards and support the process and offsite disposal of the treated product. Currently, the plan is to place the treated waste within the OU4 closure area. This treatment and subsequent placement will take place under the Corrective

Action Management Units (CAMUs) regulations, as promulgated by U.S. EPA (USEPA 40 CFR 264) and (USEPA 40 CFR 265), and the State of Colorado (Colorado 6 CCR 1007-3). These regulations allow remediation wastes to be consolidated or processed without triggering LDRs or Minimum Technology Requirements (MTRs), which were promulgated to control hazardous waste production from ongoing manufacturing activities. It is anticipated that treatment process trains will probably be permitted under RCRA Subpart X rather than Temporary Unit (TU) regulations.

The current plan to dispose of the pond sludges within the OU4 closure area must prove to be protective of human health and the environment and must meet the WAC requirements and Performance Standards. Protection of human health must be demonstrated by computer modeling. The computer model predicts which contaminants have a potential to migrate from the waste area and potentially affect human health. These contaminants have been evaluated in the treatability study.

1.4 REMEDIAL TECHNOLOGY DESCRIPTION

The goal of the treatability study is to develop a treatment process that meets the Waste Acceptance Criteria (WAC) and Performance Standards (PS) for onsite closure (see Section 1.4.1) as well as the system engineering requirements defined by the preferred treatment system (see Section 1.4.2).

1.4.1 Waste Acceptance Criteria

The objective of the treatability study is to produce a minimally treated waste that will pass the following WAC and Performance Standards (PS):

- The treatment shall be the minimum needed to meet all WAC and PS.

- The treated waste shall not, prior to placement, contain free liquids as determined by the Paint Filter Liquids Test, Method 9095 (SW 1992).

- The treated waste can be delivered as a monolith or in particulate form. If a monolith:

  - Shall fit within a rectilinear envelope 12 inches x 24 inches x 48 inches
  - Shall not exceed 3,000 pounds per square inch (psi) compressive strength
  - Shear and tensile strengths shall not exceed those of 3,000-psi concrete
  - Shall not be delivered in molds, containers, or packaging that cannot be returned

If in a particulate form:

- Shall pass a 3-inch screen
- Shall not agglomerate into particles greater than 3 inches during storage. If agglomeration does occur, the material shall meet all the criteria specified for a monolith, listed above.

- When treated waste is mixed with site soils, no agglomeration greater than 3 inches shall occur.
- Treated waste shall be resistant to dispersion by wind.
- During storage, treated waste shall not produce dust or dispersible fines and will not degrade upon wetting.
- Treatment additives shall not cause the proposed remedy to fail to be protective of human health and the environment.
- Pathogens shall be removed or rendered innocuous.
- Treated waste shall not produce gas at a rate or volume greater than that produced by natural site soil.
- Total treated waste volume shall be less than 20,000 cubic yards (cy).
- Leachate shall not contain constituents at concentrations that, when modeled, are not protective of human health and the environment.

1.4.2 Process Description

As part of the conceptual design for the treatment of pond sludge and clarifier sludge, Halliburton NUS prepared a Value Engineering Study that evaluated five potential sludge treatment alternatives to identify the treatment system that will satisfy the closure area WAC in the most efficient, reliable, and cost-effective manner, given the operating constraints present at the RFETS. The evaluation of treatment alternatives included pelletizing, extrusion, briquetting, monolith casting, and friable product. The selection of the treatment process considered the following criteria: effectiveness, implementability, operability, and cost.

The Friable Product Treatment System was recommended as the preferred alternative because it has the least potential impact on the overall project schedule, is the easiest to operate and maintain, offers the greatest operating reliability, and has the lowest total cost. A friable product is a material which resembles a cohesive soil having low strength and the properties of a treated waste in particulate form as outlined in Section 1.4.1.

The Pond Sludge Treatment System consists of the following unit process operations:

- Pond sludge transfer from interim storage tanks
- Pond sludge blending, short-term storage and feed to treatment
- Treatment additives storage and feed
- Pond sludge mixing/blending treatment with additives
- Treated waste screening and recycling of undersized treated waste
- Treated waste storage and testing
- Treated waste transfer to OU4 closure area
- Dust emissions control

The additives proposed for the treatment process are lime, which is not only a proven biocide, but is also effective in controlling moisture content; cement, for its pozzolanic properties; and a bulking agent, such as fly ash, to ensure a friable product. A block flow diagram of the proposed treatment system is shown on Figure 1-3.

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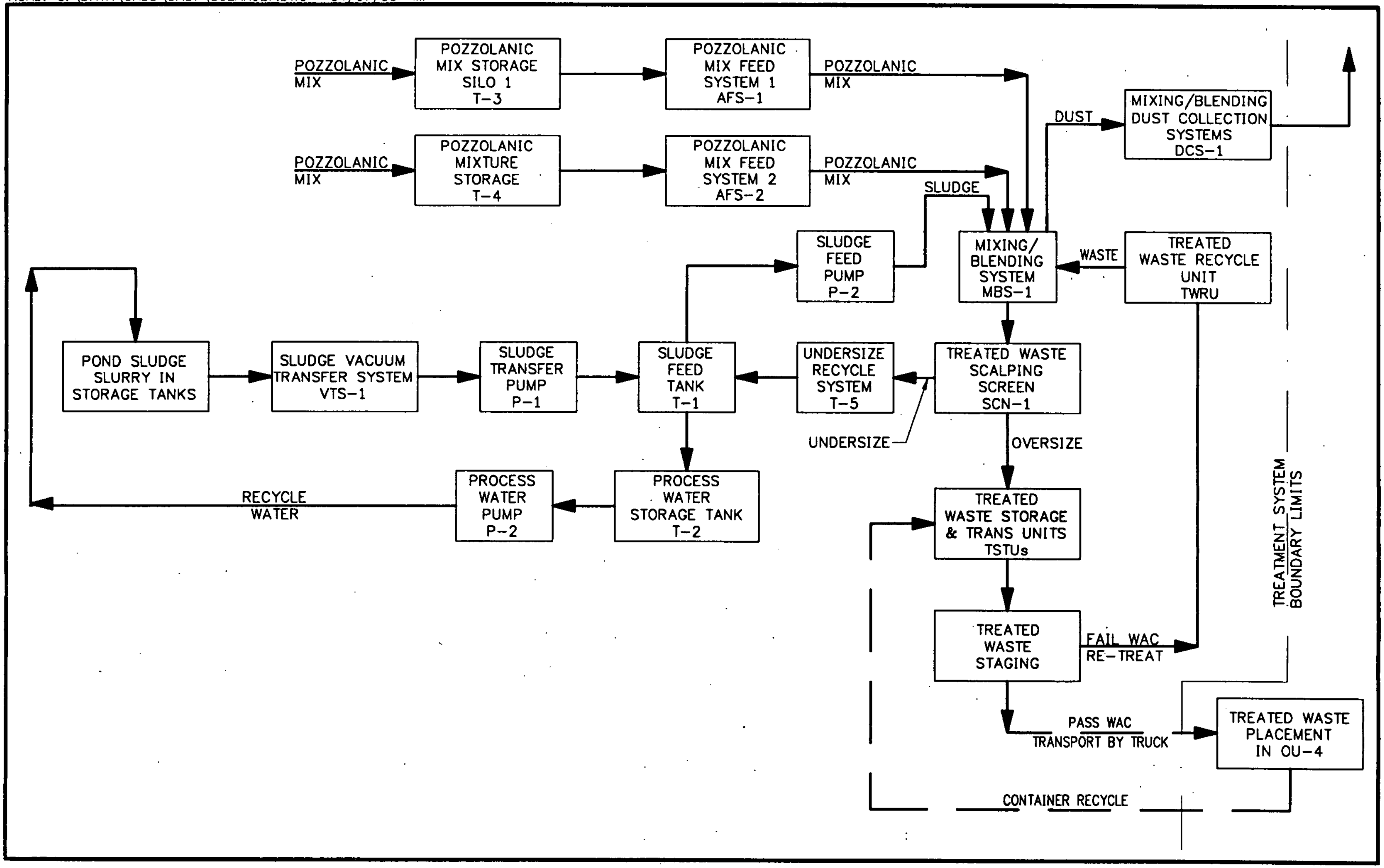

FIGURE 1-3
CONCEPTUAL BLOCK FLOW DIAGRAM
POND SLUDGE TREATMENT SYSTEM
EG&G ROCKY FLATS, GOLDEN, COLORADO

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2.0 TREATABILITY STUDY APPROACH

This section describes the requirements and procedures for conducting the treatability study used to develop the chemical stabilization/solidification (CSS) formulations for Ponds 207A, 207B (series), 207C, and Clarifier wastes at the RFETS.

2.1 GOALS AND OBJECTIVES

The goal of the treatability study was to develop a CSS formula that is successful in producing a final waste product that can be certified for disposal in accordance with the requirements as stated in Section 1.4.2 and has a final consistency of a friable soil. During the treatability study, it was necessary to determine the appropriate additives and optimum ratios of the waste to admixture(s) to achieve acceptable physical characteristics and chemical leachability criteria.

2.2 TREATABILITY STUDY OVERVIEW

The general concept used for developing process formulations for the waste form followed a progression from performing initial analysis and testing of the raw waste to screening various additives (pre-WAC testing) through a more comprehensive evaluation of additive formulations (WAC-Phase I testing). Then, finally, the selected candidate formulations that passed all of the previous evaluation criteria were subjected to final compliance testing (WAC-Phase II testing). The chronology of CSS formulation development is summarized in Table 2-1 and the logic is provided in Figure 2-1. A brief overview of the main topics of the Treatability Study are as follows:

- Initial Preparation and Characterization. The first step of the Treatability Study was to submit a uniform aliquot of the "as received" material for baseline and TCLP leachate analysis. 207A/B and Clarifier wastes were submitted in their delivered percent solids form, but the 207C material consisted of almost all crystalline material, so it was diluted with 207A/B water to achieve a 1.70 specific gravity to match characteristics of the 207C material in the tanks at the RFETS. To simulate the expected waste loading or percent total solids range of the onsite materials the percent total solids of the wastes were adjusted using 207A/B water for the treatability study testing performed.

TABLE 2-1
CHRONOLOGY OF FORMULATION DEVELOPMENT
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Phase	Waste Material	Date Performed	Testing	Objective	Results
Initial Preparation and Characterization (Baseline Analysis)	207A/B 207C Clarifier	01/04/95 01/04/95 01/03/95 12/29/94 12/29/94	• Chemical Analysis, "As Received" and TCLP - Radionuclides - Metals (Be, Cd) • Bulk Density • Percent Moisture • pH	The "as received" material was analyzed to determine the characteristics of the material. TCLP was performed on the "as received" material to determine the leachability of the untreated waste.	Results of TCLP testing, when compared to modeling data, showed that untreated pond sludge would not be protective of human health if disposed in the OU4 closure. Parameters predicted to leach above protective levels include: • 207A/B: U-238 • 207C: Pu-239/240, U-238, cadmium • Clarifier: Pu-239/240, U-238, cadmium
Lime Addition Study	207A/B 207C	01/05/95	pH and plate count	Determine lime dosage required to achieve pH > 12 for disinfection.	Able to create lime titration curve showing relationship between lime addition and pH to select an appropriate lime dosage.
Crystal Habit Modifier Study	207C	01/06/95	Physical observations	To evaluate several different chemical additives to determine the effect they have on the formation or destruction of 207C crystals in storage.	No benefit was observed in any of the chemical additives tested.
Pre-WAC Mixes	207A/B 207C Clarifier	01/13/95-01/23/95 01/24/95-01/27/95 02/02/95	Physical observations, temperature change, volumetric increases	Pre-WAC testing was performed to evaluate various types of additives and the quantities required to provide a friable soil consistency.	Based on this testing, three formulas were selected for evaluation: • $Ca(OH)_2$ and fly ash • $Ca(OH)_2$, fly ash, and silica flour • $Ca(OH)_2$, fly ash, and cement
Phase I WAC Mixes	207A/B 207C Clarifier	01/30/95-02/02/95 02/14/95-02/16/95 02/03/95-02/06/95	Physical observations, volumetric increases, TCLP analysis, UCS analysis	To establish a range of pozzolan addition which will pass both the physical requirements and WAC criteria.	Established a correlation between TCLP leachate concentration and pH, narrowed formula test to one: • $Ca(OH)_2$, fly ash, and cement
Phase II WAC Mixes	207A/B 207C Clarifier 207C and Clarifier combined	03/21/95 03/20/95 03/21/95 03/22/95	Physical observations, TCLP analysis.	To establish an operating range for key operating parameters for selected formula.	Established operating ranges for total solids content of the waste and water-to-pozzolan ratio of the treated waste.

(1) See Appendix B for development of WAC scenarios and Table B-6 for specific COC values.

- **Lime Addition Study**. A lime addition study was performed to establish a minimum lime dosage needed to achieve and maintain a pH that would inhibit future biological activity.

- **Process Formulation Development (Treatability Study Mixes)**. Treatability study mixes included friable mix development (pre-WAC) phase and WAC compliance testing (Phases I and II). All mixes were videotaped and are provided on VHS tapes. Still photographs (35 mm) of the mixes and UCS testing were also taken and are provided in Appendix E.

  - **Pre-WAC Friable Mix Development**. The mixes performed in the friable mix development phase were used to evaluate various additives. Those additives which formed a friable material were evaluated based on their bulking factor, heat generation, pH change, and curing characteristics. Those additives, or combinations of additives, which provided the most desirable qualities were retained for further evaluation.

  - **WAC Compliance Testing**. Mixes performed in the WAC compliance testing phases were used to evaluate specific CSS formulas to determine WAC compliance. Two phases were performed as discussed below.

    - **Phase I**. Mixes performed in Phase I were used to evaluate the additive(s) selected in the pre-WAC testing for compliance with the WAC criteria. To develop an operating range of key parameters, mixes were performed at different percent solids of the waste and water-to-pozzolan ratios. Figure 2-2 provides a schematic of the mixes performed.

    - **Phase II**. Mixes performed during Phase II were used to further evaluate the formula selected in Phase I. During preparation of these mixes, the percent solids of the waste feed, the water-to-pozzolan ratio, and the amount of lime added were adjusted to establish a process operating range for these parameters. A schematic of the mixes performed is provided in Figure 2-3.

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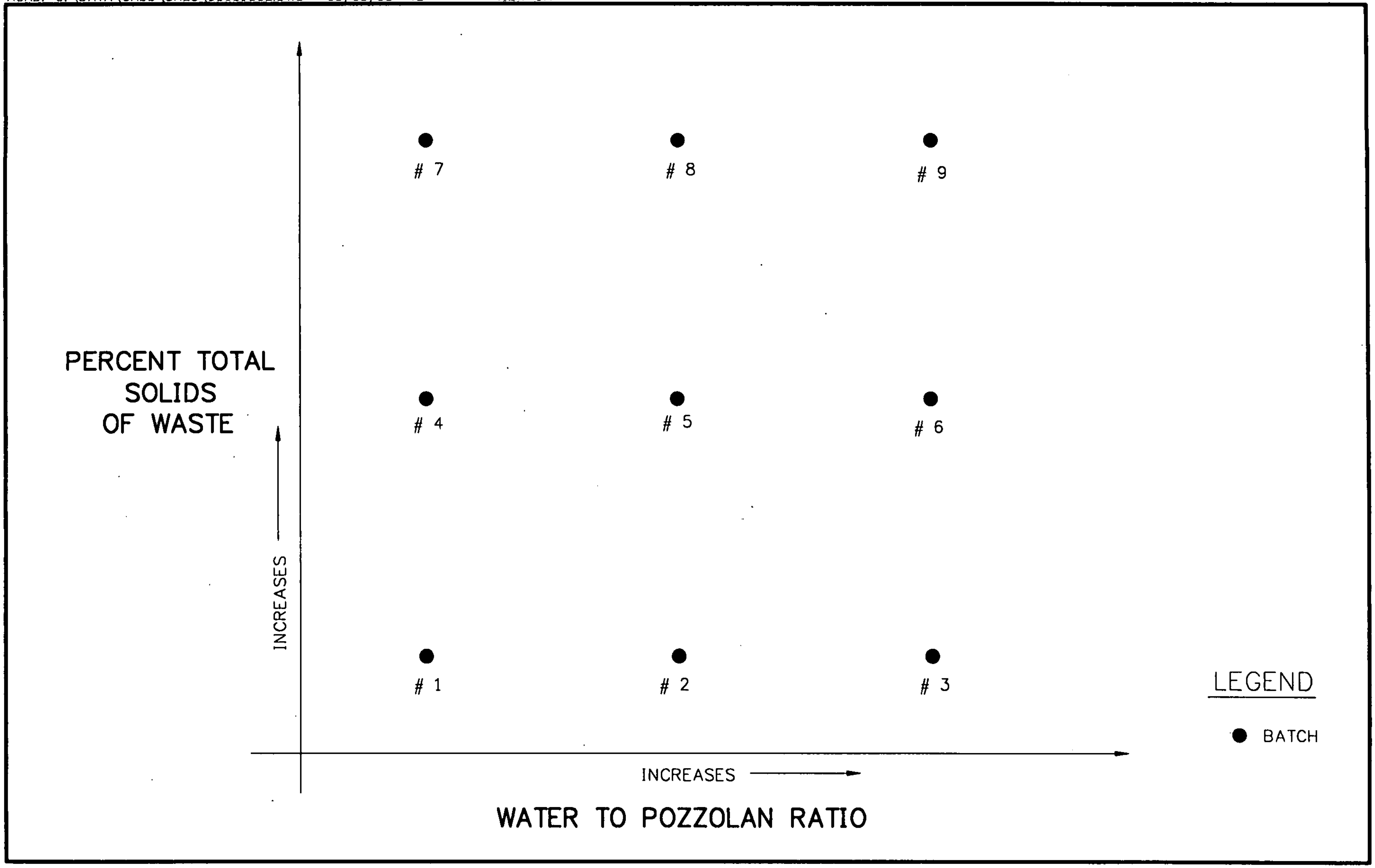

**WASTE LOADING AND POZZOLAN ADDITION VARIATIONS
FOR WAC PHASE I TESTING
ROCKY FLATS, COLORADO**

FIGURE 2-2

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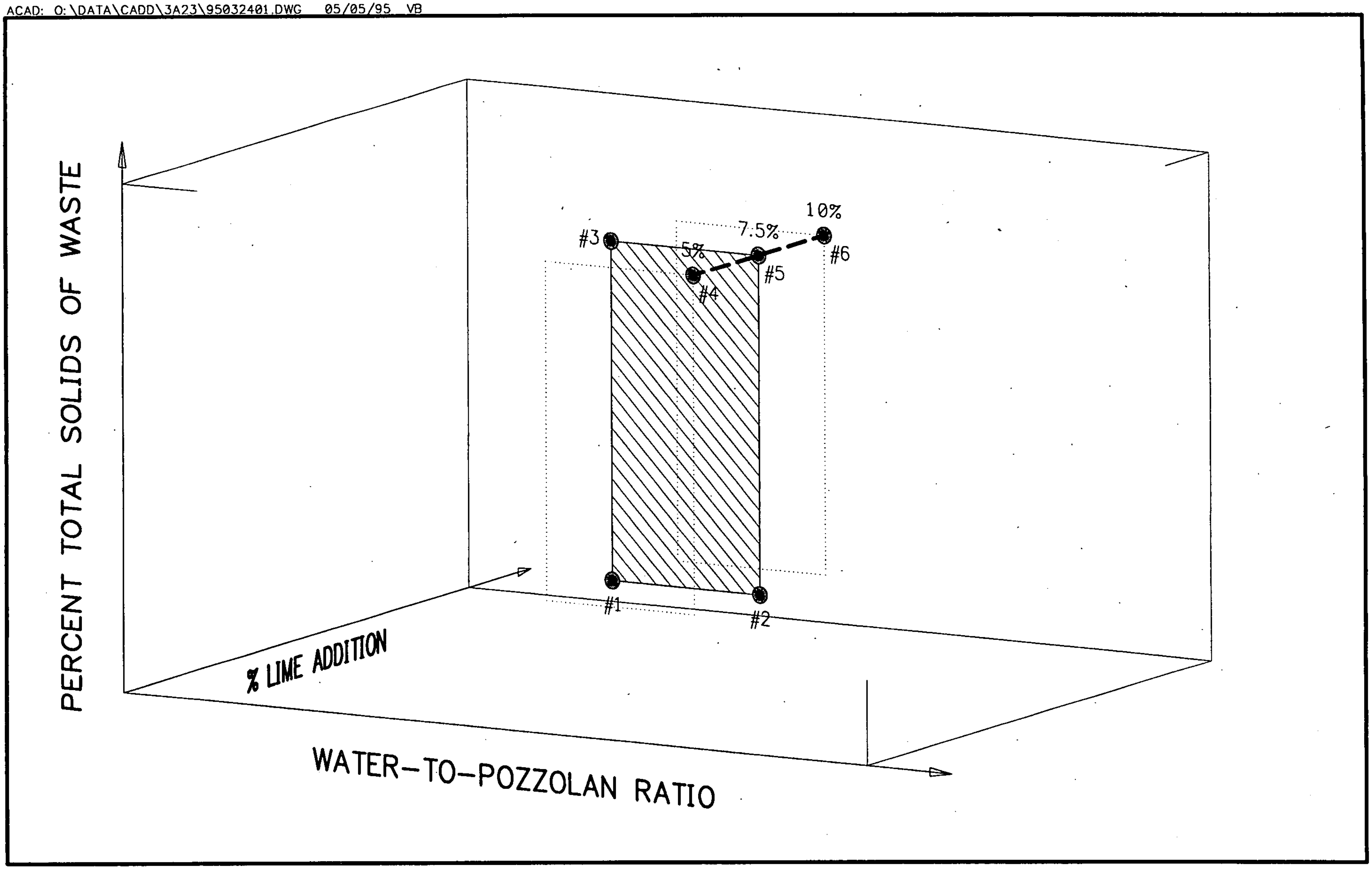

FIGURE 2-3

WASTE LOADING AND ADDITION VARIATIONS
FOR WAC PHASE II TESTING
ROCKY FLATS, COLORADO

Halliburton NUS CORPORATION

The analytical program for the WAC Compliance Phase testing is provided in Table 2-2. The rationale for each analysis is provided below.

- Unconfined compressive strength (UCS) provides an estimate of the final product's agglomerated strength and allows comparisons with other formulations.

- The Paint Filter Liquids Test is required to verify that there are no free liquids present.

- TCLP analysis is required to evaluate whether the final waste form meets the WAC requirement for protectiveness of human health.

2.3 EQUIPMENT AND MATERIALS

2.3.1 Mixed-Waste Treatability Study Laboratory

The testing conducted for the CSS treatability study was performed at the HNUS Laboratory in Pittsburgh, Pennsylvania. The work was performed in a treatability room that was specifically designed to accommodate low-level mixed waste materials. The room has double air locks for entrance and exit along with a negative air ventilation system which exhausts air through High Efficiency Particulate Air (HEPA) filters. All personnel entering this secured area are required to wear personal protective equipment (Tyvek coverall, booties, and nitrile gloves). Personnel must also wear dosimetry badges and rings. Additionally, all personnel must submit annual bioassays for radionuclide analysis.

2.3.2 Laboratory Equipment

All major equipment used for the solidification portions of the treatability study is listed in Table 2-3. This table provides the manufacturer, model number, and pertinent equipment specifications.

TABLE 2-2

SUMMARY OF TESTING PERFORMED ON MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Analysis	Method		Test Performed	
	Sludges and Solids	Liquids and Extracts	WAC Phase I	WAC Phase II
Unconfined Compressive Strength (UCS)	ASTM D4219-83	NA	Yes	No
Paint Filter Liquids Test	SW 9095	NA	Yes	Yes
Specific Gravity	ASTM D34.02-025RE	ASTM D429	Yes	No
Bulk Density	(1)	(1)	Yes	No
TCLP Leach	SW 1311	---	Yes	Yes
pH	SW 9045	EPA 150.1	Yes	Yes
Cadmium (ICP)	SW 3050/6010	SW 3010/6010	Yes	Yes
Beryllium (GFAA)	SW 3050/7091	SW 3020/7091	Yes	Yes
Nitrate/Nitrite	NA	EPA 353.2	Yes	Yes
Arsenic (GFAA)	SW 3050/7060	SW 3020/7060	No	Yes
Chromium (ICP)	SW 3050/6010	SW 3010/6010	No	Yes
Lead (GFAA)	SW 3050/7421	SW 3020/7421	No	Yes
Sodium (ICP)	SW 3050/6010	SW 3010/6010	No	Yes
Americium-241	(2)	(2)	Yes	Yes
Plutonium-239/240	(2)	(2)	Yes	Yes
Uranium-233/234	(2)	(2)	Yes	Yes
Uranium-235	(2)	(2)	Yes	Yes
Uranium-238	(2)	(2)	Yes	Yes

TABLE 2-2 (Continued)
SUMMARY OF TESTING PERFORMED ON MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Analysis	Methods		Test Performed	
	Sludges and Solids	Liquids and Extracts	WAC Phase I	WAC Phase II
Cesium-134	EPA 901.1	EPA 901.1	Yes	Yes
Cesium-137	EPA 901.1	EPA 901.1	Yes	Yes
Radium-226	EPA 903.1	EPA 903.1	Yes	Yes

(1) Agronomy No. 9 - "Methods of Soil Analysis, Part I," American Society of Agronomy, 1965.

(2) Alpha spectrometry preparation method: "Precipitation of Actinides as Fluorides or Hydroxides for High Resolution Alpha Spectrometry," Claude W. Sill, Nuclear and Chemical Waste Management, Vol. 7, pp. 201-215.
Alpha spectrometry counting reference: Digital Multiplexer Router II and instruction manual, Tennelac/Nucleus, Inc.

ASTM, 1988	"Annual Book of ASTM Standards," American Society for Testing and Materials.
EPA, 1983	"Methods for Chemical Analyses of Water and Wastes," Environmental Protection Agency, 1979, Revised March 1983.
SM, 1989	"Standard Methods for the Examination of Water and Wastewater," American Public Health Association. 17th Edition. EPA's list of approved methods (40 CFR 136) currently references the 17th edition.
SW, 1992	"Tests Methods for Evaluating Solid Waste-Physical/Chemical Methods," Environmental Protection Agency, SW846, 3rd Edition, Revised July 1992.
TCLP	Toxicity Characteristic Leaching Procedure.
WAC	Waste Acceptance Criteria, Phases I and II.
NA	Not Applicable

TABLE 2-3

LABORATORY EQUIPMENT SUMMARY
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Equipment	Manufacturer	Model No.	Pertinent Specifications
Mixer	Hobart	N-50	Motor Rating: 1/6 HP, 1,725 RPM, Single Phase, 115 V, 60 HZ, 2.85 Amps
Unconfined Compressive Strength	Geotest Instrument Corporation	S2013	Max. Load Ring = 2,000 lb.
Balance	Denver Instrument Company	XD-12K	Range: 0.1 - 5,000.0 grams
Drying Oven	Fisher Scientific Isotemp® Oven	655F	Accuracy ± 2°F
Stirrer (T-Line Laboratory Stirrer)	Talboys Engineering Company	134-1	NA
Temperature Gauge	Fisher Scientific Digital Thermometer	NA	-40.0 through 300°F -40.0 through 150.0°C
pH Meter	Fisher Scientific Digital pH Meter	Field Model	± 1 (non-analytical use only)

2.3.3 CSS Material Specifications

The materials used for the waste acceptance criteria CSS formulas include lime, fly ash, silica flour, and cement. Material Safety Data Sheets for these materials are provided in Appendix D. These materials were submitted for radiological and metal laboratory analyses and the results are also provided in Appendix D.

The lime used was a high calcium hydrated lime manufactured by Mississippi Lime Company, St. Genevieve, Missouri. The typical specifications for a high calcium hydrated lime are as follows:

- Specific Gravity: 2.3 to 2.4
- Bulk Density: 25 to 35 lb./cu. ft.
- Specific Heat at 100° F: 0.29 BTU/Lb.
- Contains less than 5% magnesium oxide
- Contains less than 1% unhydrated oxides

The cement used for the CSS formula development is classified as Type I/II cement manufactured by Southwestern Portland Cement, Mountain Division, Lyons, Colorado. Type I/II is a general purpose cement with moderate exposure resistance to sulfate attack.

The fly ash that was used for the CSS formulas was Type C, which meets the ASTM C618 specification. Two different sources of Type C fly ash were used, both supplied by the Western Ash Company. One was from the Comanche power plant, and the other was from the Pawnee power plant. The Pawnee fly ash was used for the majority of the testing. The two fly ashes are similar in chemical make-up and physical characteristics.

2.3.4 Solubility Considerations

Waste acceptance criteria (WAC) for various metals and radionuclides at the site are based upon the proposed Interim Measure/Interim Remedial Action (IM/IRA) closure plan, which includes a cap with no lateral groundwater controls and an estimated infiltration rate of 0.0068 inches per year. A numerical model was applied to the OU4 closure to estimate the concentrations of contaminants in the leachate that are protective of human health at the point of exposure. The criteria are applied by evaluating the leachability (as measured by the Toxicity Characteristic Leaching Procedure [TCLP]) of the various chemically stabilized/solidified waste sludges evaluated in this treatability study. The treated waste is deemed to be protective of human health if the TCLP leachate concentration is less than the criteria predicted by the model.

The selected CSS formulation included additions of lime, fly ash, and cement to the waste sludges. These additives supplied alkalinity in the form of hydroxides and some carbonates to the waste mixtures in sufficient quantities to raise the pH above 12. At this pH, the addition of acid in the TCLP procedure still results in the pH of the leachate in excess of 11. Leachability or contaminant mobility in this high pH matrix is tied to the solubility of various radionuclide and metal hydroxide species (Linke, W.F., 1958) and (Dean, J.A., 1979). In water-chemistry, there typically exists a pH range where the speciation of a certain metal hydroxide is such that the greatest portion will form an insoluble precipitate (Faust & Aly, 1983). These optimum pH ranges vary by compound and are typically in the range of 8-12. Optimum ranges for the radionuclide and metal hydroxides present at Operable Unit 4 (OU4) are shown in Figure 2-4.

At lower pHs, there is not sufficient hydroxide concentration to create significant amounts of the insoluble compound, whereas, above the high end of the optimum pH range, the formation of soluble complexes tend to redissolve the insoluble precipitates (Stumm & Morgan, 1970).

Although a problem in wastewater treatment, exceeding the high end of the optimum pH range is not a concern in the solidification/stabilization process. Because of their large size compared to free metal ions present at lower pH, most soluble complexes which may tend to form are more susceptible to being chemically bound into the matrix of the solidified/stabilized material (Conner, J.R., 1990). The ability to stabilize the waste is the same whether the material is solidified into a monolith or into a friable soil-like material such as in the case at OU4. In addition, the ability of the cement to take up excess moisture in the final product also aids in reducing the mobility of the various radionuclides and heavy metals of concern.

2.4 POND 207A/B TREATABILITY STUDY TESTING

Testing of 207A/B included a baseline evaluation of the as received material, a lime addition study, friable mix development (pre-WAC mixes), and WAC compliance testing (Phases I and II mixes).

2.4.1 Initial Preparation and Characterization

The 207A/B material was delivered to the HNUS laboratory on December 9, 1994, in a double-lined, 30-gallon, metal, open-top, bolt-secured lid drum. The material was a brownish-gray with the consistency of sandy topsoil and had a septic smell. The material was submitted for baseline analysis and TCLP baseline analysis. For WAC testing, this material was diluted with 207A/B water to a range of 10% to 30% solids.

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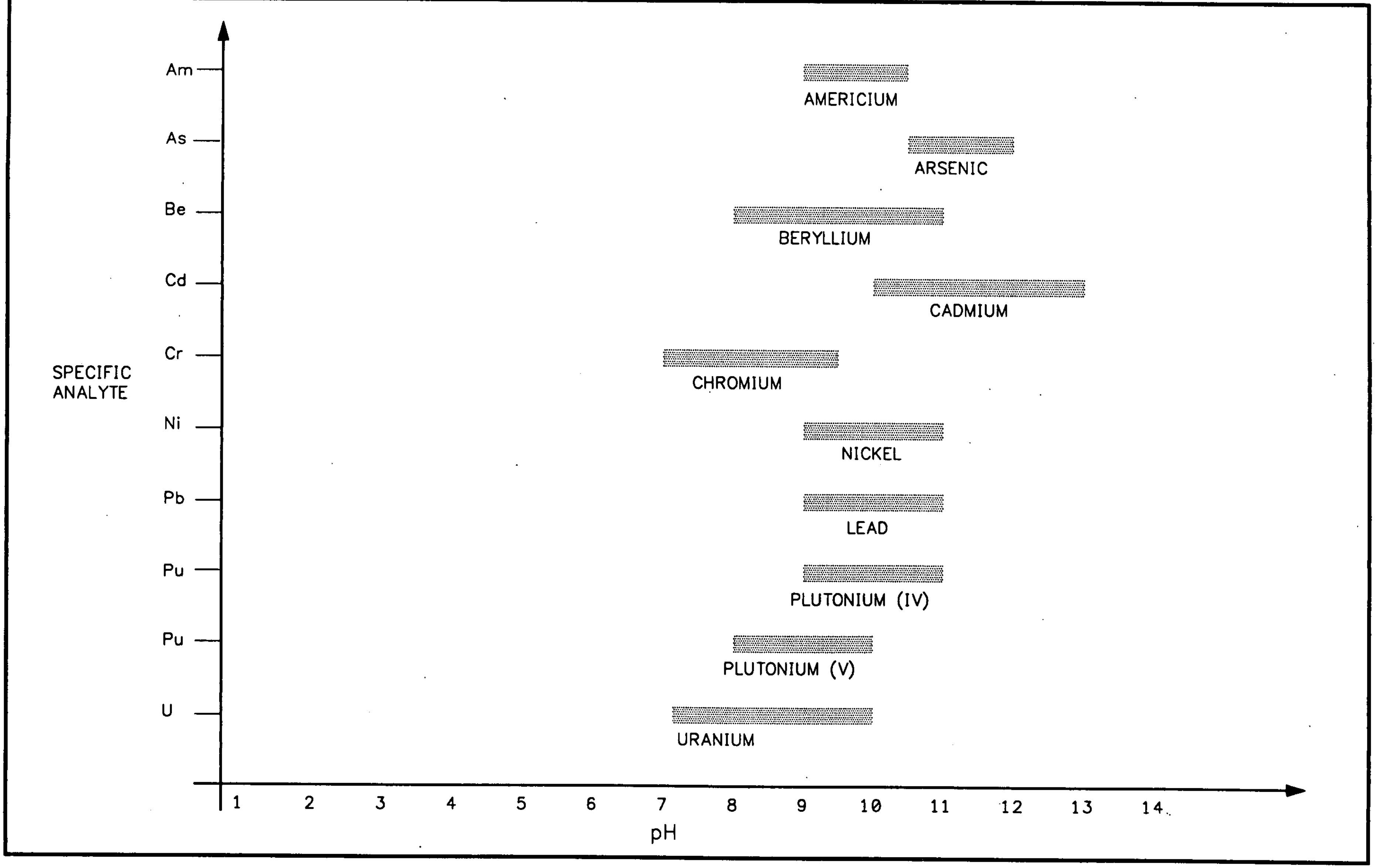


OPTIMUM pHs FOR PRECIPITATION
OF VARIOUS METAL HYDROXIDES
ROCKY FLATS, COLARADO

FIGURE 2-4

Halliburton NUS CORPORATION

2.4.2 Lime Addition Study

One of the waste acceptance criteria for disposal of pond sludge within the OU4 closure area is that the treated waste cannot generate gas at a rate greater than the rate associated with native soil. Gas can be generated by the biological decomposition of organic material. Previous characterization data have shown that the pond sludges contain a significant amount of organic material, measured as total organic carbon (TOC), which is available for biological decomposition by microorganisms. The TOC concentrations ranged from 14,000 mg/kg in Pond 207A sludge to 3,200 mg/kg in Pond 207B (north) sludge. Samples of pond sludge stored in containers during previous treatability testing generated gas, confirming the potential of the treated sludge to violate the WAC.

A study was conducted on Pond 207A/B sludge to assess the effectiveness of lime in stabilizing the sludge by elevating the pH. Considerable data are available supporting the use of lime to raise the pH to stabilize biological sludges. Most of the data are from studies conducted on the stabilization of municipal sewage sludges and septage in support of land disposal of these materials. This information is readily available from guidance documents and process design manuals published by the U.S. Environmental Protection Agency (USEPA). A brief synopsis of several documents is as follows:

- In the USEPA's Process Design Manual for Upgrading Existing Wastewater Treatment Plants (USEPA, 1974), the authors cite several studies that "have reported that the addition of lime to raw or digested sludges to pH ranges of 10.2 to 12.5 has effectively reduced the number of pathogenic organisms present. Current USEPA-sponsored work indicates that the pH should be increased to 12.0 for more effective disinfection."

- The USEPA's Process Design Manual, Wastewater Treatment Facilities for Sewered Small Communities (USEPA, 1977) states that "if the pH is raised to between 12.2 to 12.4 and then kept above 11 for 14 days, the sludge will be stabilized."

- More recent guidance contained in the USEPA's Guide to Septage Treatment and Disposal (USEPA, 1994) indicates that increasing the pH to 12 for 30 minutes meets the Federal requirements for lime stabilization of septage.

Based on the references cited, it appears that achieving and maintaining a pH of 12 is sufficient to stabilize municipal sewage sludge or septage. Since the pond sludge reportedly received only relatively minor quantities of sewage sludge compared to the total volume of the ponds, this method of treatment should be more than adequate to reduce the potential for future gas generation.

The goals of the lime addition study were to determine the dosage of lime needed to stabilize the sludge and to determine whether hydrated lime ($Ca(OH)_2$) or quicklime (CaO) was more advantageous. Small dosages of lime (both hydrated lime and quicklime) were incrementally added to a known quantity of Pond 207A/B sludge, prepared at 20% solids. Samples were collected for pH analysis and bacterial standard plate count. The pH was measured during testing to ensure that values were obtained over the pH range from that of the raw waste to greater than 12. This data was then plotted to graphically show the dosages of lime needed to achieve the target pH.

2.4.3 Process Formulation Development

Mixes were performed to develop a process formulation and subsequent process range that achieves the established goals. Mixes performed in the friable mix development phase were used to evaluate a wide range of additives to establish a formulation that provided a friable mix. The mixes performed in the WAC compliance testing phase were used to establish a process range and to evaluate the formulas for WAC acceptance. These phases are discussed in further detail below.

2.4.3.1 Pre-WAC Friable Mix Development

The objective of the treatability study is that the final CSS mix has the consistency of a friable soil while still being able to pass all other WAC criteria. To achieve this, a wide range of additives were evaluated to determine their ability to satisfy all of the desired final product properties. Additives tested included hydrated lime ($Ca(OH_2)$), quick lime (CaO), fly ash (Type C), cement (Type I/II), CalSeal (gypsum hemihydrate), silica flour, Stardust (amphorus silica), and several combinations of these additives. Based on the results of this test, the list of additives or combination of additives was able to be narrowed down to a select few which were retained for further evaluation in subsequent phases.

The pre-WAC mixes were prepared by adding lime to the waste feed material and mixing on low speed for 5 minutes. The additive was then added in the specific ratios, in increments of 50 grams, until a friable mix was achieved. Observations were made and videotaping was performed after each addition. A final volume and temperature was recorded and the material was placed in a bag for further use, if required.

2.4.3.2 WAC Compliance Testing

Phase I. The goal of this phase of the treatability study was to evaluate the selected additive combinations, established in the pre-WAC study, for compliance with the waste acceptance criteria and desired final mix consistency. The combination of additives tested included:

- Lime and fly ash
- Lime, fly ash, and silica flour
- Lime, fly ash, and cement

Several mixes were performed attempting to establish physical and chemical boundaries for the various mixes. The 207A/B waste material was added at various percent total solids and the amount of pozzolans added were varied in relationship to the amount of water available in the feed waste. The pozzolans act to form a stable product by eliminating the free water and adjusting the pH. Table 2-4 provides a summary of the mixes performed.

The mixes were prepared in a Hobart mixer on speed setting No. 2, which is an aggressive, higher rpm setting. The additives were added in one bulk addition to the waste feed material (207A/B at various percent solids) and permitted to mix for 2 minutes and 30 seconds. Observations of the materials' consistency were made and video recordings were taken. The final product was then placed in a plastic cylinder mold (2-inch-diameter by 4-inch-diameter) and a plastic bag for curing. After 24 hours the material in the plastic bags was processed through a 3/8-inch-diameter sieve and submitted for TCLP analysis. The cylinders were allowed to cure for 48 hours at which point they were tested for UCS.

Information obtained on the physical, analytical, and UCS results helped select a representative mix for final confirmation testing (WAC Phase II).

Phase II. A group of mixes was performed using lime and fly ash, and lime, fly ash and cement, in order to establish a relationship between the lime dosage, duration of curing, and pH of the TCLP leachate. These mixes were prepared using 207A/B at 20% solids. The water-to-pozzolan (W/P) ratio was held constant for all mixes, but the amount of lime was varied. Testing was performed at 5%, 10%, and 15% lime by weight of feed material. Sample curing time was independently varied and tested at 24 hours, 48 hours, 72 hours, and 7 days. A summary of the results of the mixes is provided in Table 2-5. Based on the testing results of the lime dosage/curing time study and the Phase I evaluation, the formulation using lime, fly ash, and cement was selected for final WAC Phase II mix testing and analysis.

TABLE 2-4

SUMMARY OF 207 A/B WAC PHASE I MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Total Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly ash/Cement/ Silica Flour Ratio
1	01/30/95	10	0.24	38.4	1 / 0 / 0
2	01/30/95	10	0.28	38.4	1 / 0 / 0
3	01/30/95	10	0.34	38.4	1 / 0 / 0
4	01/30/95	20	0.24	34.0	1 / 0 / 0
5	01/30/95	20	0.28	34.0	1 / 0 / 0
6	01/30/95	20	0.34	34.0	1 / 0 / 0
7	01/30/95	30	0.24	29.6	1 / 0 / 0
8	01/30/95	30	0.28	29.6	1 / 0 / 0
9	01/30/95	30	0.34	29.6	1 / 0 / 0
1A	01/31/95	10	0.20	5.0	5.67 / 0 / 1
2A	01/31/95	10	0.25	5.0	5.67 / 0 / 1
3A	01/31/95	10	0.30	5.0	5.67 / 0 / 1
4A	01/31/95	20	0.20	5.0	5.67 / 0 / 1
5A	01/31/95	20	0.25	5.0	5.67 / 0 / 1
6A	01/31/95	20	0.30	5.0	5.67 / 0 / 1
7A	01/31/95	30	0.20	5.0	5.67 / 0 / 1
8A	01/31/95	30	0.25	5.0	5.67 / 0 / 1
9A	01/31/95	30	0.30	5.0	5.67 / 0 / 1
1B	02/01/95	10	0.20	5.0	2 / 1 / 0
2B	02/01/95	10	0.25	5.0	2 / 1 / 0
3B	02/01/95	10	0.30	5.0	2 / 1 / 0
4B	02/01/95	20	0.20	5.0	2 / 1 / 0
5B	02/01/95	20	0.25	5.0	2 / 1 / 0
6B	02/01/95	20	0.30	5.0	2 / 1 / 0
7B	02/01/95	30	0.20	5.0	2 / 1 / 0
8B	02/01/95	30	0.25	5.0	2 / 1 / 0
9B	02/01/95	30	0.30	5.0	2 / 1 / 0
1C	02/02/95	20	0.59	135.4	0 / 0 / 0
2C	02/02/95	20	0.31	5.0	0 / 1 / 0
1D	02/02/95	10	0.24	38.4	1 / 0 / 0
2D	02/02/95	30	0.20	5.0	2 / 1 / 0

Note: Mixes 1D and 2D were duplicate mixes of 1A and 7B, respectively. These were done for laboratory quality control requirements.

The above mixes were recorded on videotapes numbered 1 and 3 entitled "207A/B Mixes."

TABLE 2-5

207A/B WAC PHASE II
CURING TIME AND LIME ADDITION STUDY
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Total Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly ash/ Cement Ratio	Curing Time
1A	03/08/95	20	0.23	5	1 / 0	24 hours
2A	03/08/95	20	0.23	5	1 / 0	48 hours
3A	03/08/95	20	0.23	5	1 / 0	72 hours
4A	03/08/95	20	0.23	5	1 / 0	7 days
1B	03/08/95	20	0.23	10	1 / 0	24 hours
2B	03/08/95	20	0.23	10	1 / 0	48 hours
3B	03/08/95	20	0.23	10	1 / 0	72 hours
4B	03/08/95	20	0.23	10	1 / 0	7 days
1C	03/08/95	20	0.23	15	1 / 0	24 hours
2C	03/08/95	20	0.23	15	1 / 0	48 hours
3C	03/08/95	20	0.23	15	1 / 0	72 hours
4C	03/08/95	20	0.23	15	1 / 0	7 days
1D	03/08/95	20	0.23	5	2 / 1	24 hours
2D	03/08/95	20	0.23	5	2 / 1	48 hours
3D	03/08/95	20	0.23	5	2 / 1	72 hours
4D	03/08/95	20	0.23	5	2 / 1	7 days
1E	03/08/95	20	0.23	10	2 / 1	24 hours
2E	03/08/95	20	0.23	10	2 / 1	48 hours
3E	03/08/95	20	0.23	10	2 / 1	72 hours
4E	03/08/95	20	0.23	10	2 / 1	7 days
1F	03/08/95	20	0.23	15	2 / 1	24 hours
2F	03/08/95	20	0.23	15	2 / 1	48 hours
3F	03/08/95	20	0.23	15	2 / 1	72 hours
4F	03/08/95	20	0.23	15	2 / 1	7 days

The 207A/B material was tested at solids loadings of 10% and 30%. The water-to-pozzolan (W/P) ratios were held at 0.2 and 0.3 for both loadings using a fly ash to cement ratio of 2:1. The amount of hydrated lime added was 7.5% by weight of waste feed. Lime addition was varied from 5% to 10% lime by weight of waste feed on the selected mix which consisted of 30% solids and a w/p ratio of 0.30. A summary of the selected mix is provided in Table 2-6.

Samples were collected and analyzed to assess the CSS formulations for TCLP. Samples of stabilized waste were collected after 24 hours of curing by removing the stabilized waste from the plastic bags, and were then crushed to pass through a 3/8 inch sieve in accordance with Method 1311 (SW 1992). After samples received a tracking number, standard laboratory chain-of-custody procedures were followed as described in the NUS Laboratory General Quality Assurance Manual.

Only those analyses which are required for final product certification are analyzed by SW-846 with CLP-type deliverables. Analyses were conducted according to SW-846, but were analyzed with the intention of being used for engineering data (i.e., CLP-like deliverables are not provided and data is not validated).

2.5 POND 207C TREATABILITY STUDY TESTING

Testing of 207C included a baseline evaluation of the 207C material prepared to 1.7 specific gravity (S.G.) using 207C material, as received, and 207A/B water; a lime addition study; friable mix development (pre-WAC mixes), a crystal habit modifier study; and WAC compliance testing (Phases I and II mixes).

2.5.1 Initial Preparation and Characterization

The 207C material was delivered to the NUS Pittsburgh Laboratory on December 9, 1994, in a double-lined, 30-gallon, metal, open-top, bolt-secured lid drum. The material was greenish in color with 1 inch of free liquid above a dense slurry. No distinct odor was observed. The material was tested for specific gravity using the Halliburton NUS mud balance. The as received material was approximately 2.01 S.G. A portion of this material was diluted to a specific gravity of 1.7 using pond 207A/B water and submitted for baseline analysis and TCLP baseline analysis.

2.5.2 Lime Addition Study

For the same reasons stated in Section 2.4.2, a lime study was performed on the 207C material. Two types of lime were tested, hydrated lime [$Ca(OH)_2$] and quicklime [CaO]. Both limes were tested at additions of 0.28%, 0.7%, 1.4%, 2.8%, and 5.7% by weight of waste material. The quicklime was also tested at a 11.4%

TABLE 2-6

SUMMARY OF 207 A/B WAC PHASE II MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly Ash/Cement Ratio
1	03/20/95	10	0.20	7.5	2 / 1
2	03/20/95	10	0.30	7.5	2 / 1
3	03/20/95	30	0.20	7.5	2 / 1
4	03/20/95	30	0.30	5.0	2 / 1
5	03/21/95	30	0.30	7.5	2 / 1
6	03/21/95	30	0.30	10.0	2 / 1

Note: The above mixes were recorded on video tape entitled: Video Tape #2 - "207A/B Mixes."

addition. These samples were also submitted for bacteriological plate count analysis to determine the disinfection capabilities of lime.

2.5.3 Crystal Habit Modifier Study

It is more difficult to stabilize and process 207C in its crystalline state rather than its liquid state. Therefore, in an attempt to control or reduce the crystal growth of the 207C crystals, tests were performed with a variety of additives. This was accomplished by placing aliquots of the 207C material into graduated cylinders and measuring the aqueous and solid/crystalline phases. The crystal habit modifiers were then added at 1.5 to 15% by weight to the Pond 207C material. The mixture was slurried and allowed to set. Visual observations were noted and a measurement of the phases was taken. The following products were tested:

- HR-4 additive (modified lignosulfonate) - Halliburton product
- HR-12 additive (modified lignosulfonate) - Halliburton product
- HR-15 additive (sulfamethylated lignin) - Halliburton product
- HR-25 additive - (alpha hydroxy organic acid) - Halliburton product
- Scalechek LP-25 Scale Inhibitor (ethylene glycol polyacrylate) - Halliburton product
- CFR-1 Cement Friction Reducer (alpha hydroxy organic acid) - Halliburton product
- 8003 (amide) - Champion Technologies product

All of the above-mentioned products work in a similar fashion. Crystal habit modifiers are known as nucleation poisoners or nucleation inhibitors. Compounds of this type are used extensively to prevent fouling of industrial equipment and water treatment plants. The compounds primarily work by absorption onto the surface of initially formed nuclei. The crystalline surface is then altered in such a way that the extensive lattice characteristic of large crystals cannot form. For some of the additives, chelation also contributes in preventing crystal formation. The net result of these interactions is that the species of interest remain in solution or suspended.

2.5.4 Process Formulation Development

Mixes were performed to develop a process formulation and subsequent process range which achieves the established goals. Mixes performed in the friable mix development phase evaluated a wide range of additives to establish a formulation which provided a friable mix. The mixes performed in the WAC compliance testing phase attempted to establish a process range and evaluated the formulas for WAC acceptance. These phases are discussed in further detail below.

2.5.4.1 Pre-WAC Friable Mix Development

In an attempt to achieve a friable soil mix and determine the approximate type and amount of pozzolan addition needed, several pre-WAC mixes were performed. Based on the results of the 207A/B pre-WAC mixes and crystal habit modifier study, the list of additives included hydrated lime, quicklime, fly ash, cement, CalSeal, and silica flour. These additives were tested alone or in conjunction with one or more of the others. The mixes were evaluated on bulking factor, heat generation, pH adjustment, and physical characteristics. Based on the results of the mixes, representative formulas were selected for further evaluation.

2.5.4.2 WAC Compliance Testing

Phase I. The goal of this phase of the treatability study was to evaluate the selected additive combinations, established in the pre-WAC study, for compliance with the waste acceptance criteria and desired final mix consistency. The combination of additives tested include:

- Lime and fly ash
- Lime, fly ash, and silica flour
- Lime, fly ash, and cement

Several mixes were performed attempting to establish an operating range for the various mixes. The 207C waste material was added at various percent solids and the amount of pozzolans added were varied in relationship to the amount of water available in the feed waste. Table 2-7 provides a summary of the mixes performed.

The mixes were prepared in a mixer on speed setting No. 2, which is a very aggressive, higher revolutions per minute (rpm) setting. The additives were added in one bulk addition to the waste feed material (207C at various percent solids) and permitted to mix for 2 minutes and 30 seconds. Observations of the materials' consistency was made and video recordings were taken. The final product was then placed in a plastic cylinder mold and plastic bag for curing. After 24 hours the material in the plastic bags was processed through a 3/8-inch-diameter sieve and submitted for TCLP analysis. The cylinders were allowed to cure for 48 hours, at which point they were tested for UCS.

Information obtained on the physical, analytical, and UCS results helped select a representative mix which was selected for final confirmation testing (WAC Phase II).

TABLE 2-7

SUMMARY OF 207C WAC PHASE I MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Total Solids	Specific Gravity	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly ash/Cement/ Silica Flour Ratio
1A	02/14/95	56.3	1.5	0.10	5.0	1 / 0 / 0
2A	02/14/95	56.3	1.5	0.20	5.0	1 / 0 / 0
3A	02/14/95	56.3	1.5	0.30	5.0	1 / 0 / 0
4A	02/14/95	70.8	1.75	0.10	5.0	1 / 0 / 0
5A	02/14/95	70.8	1.75	0.20	5.0	1 / 0 / 0
6A	02/14/95	70.8	1.75	0.30	5.0	1 / 0 / 0
7A	02/14/95	82.5	1.98	0.10	5.0	1 / 0 / 0
8A	02/14/95	82.5	1.98	0.20	5.0	1 / 0 / 0
9A	02/14/95	82.5	1.98	0.30	5.0	1 / 0 / 0
1B	02/15/95	56.3	1.5	0.15	5.0	2 / 1 / 0
2B	02/15/95	56.3	1.5	0.20	5.0	2 / 1 / 0
3B	02/15/95	56.3	1.5	0.25	5.0	2 / 1 / 0
4B	02/15/95	70.8	1.75	0.15	5.0	2 / 1 / 0
5B	02/15/95	70.8	1.75	0.20	5.0	2 / 1 / 0
6B	02/15/95	70.8	1.75	0.25	5.0	2 / 1 / 0
7B	02/15/95	82.5	1.98	0.15	5.0	2 / 1 / 0
8B	02/15/95	82.5	1.98	0.20	5.0	2 / 1 / 0
9B	02/15/95	82.5	1.98	0.25	5.0	2 / 1 / 0
1C	02/16/95	56.3	1.5	0.15	5.0	5.67 / 0 / 1
2C	02/16/95	56.3	1.5	0.20	5.0	5.67 / 0 / 1
3C	02/16/95	56.3	1.5	0.25	5.0	5.67 / 0 / 1
4C	02/16/95	70.8	1.75	0.15	5.0	5.67 / 0 / 1
5C	02/16/95	70.8	1.75	0.20	5.0	5.67 / 0 / 1
6C	02/16/95	70.8	1.75	0.25	5.0	5.67 / 0 / 1
7C	02/16/95	82.5	1.98	0.15	5.0	5.67 / 0 / 1
8C	02/16/95	82.5	1.98	0.20	5.0	5.67 / 0 / 1
9C	02/16/95	82.5	1.98	0.25	5.0	5.67 / 0 / 1

Note: The above mixes were recorded on videotape No. 2 entitled "207C Mixes."

Phase II. Using lime and fly ash, and lime, fly ash and cement, a group of mixes were performed to establish a relationship between the lime dosage, duration of curing, and final TCLP leachate pH. These mixes were prepared using 207C at 70.8% solids Specific Gravity (S.G.) = 1.75. The W/P ratio was held constant for all mixes at 0.23, but the amount of lime was varied. Tests were conducted at 5%, 10%, and 15% lime by weight of feed material. The curing time was also independently varied and tested at 24 hours, 48 hours, 72 hours, and 7 days. A summary of the results of the mixes is provided in Table 2-8. Based on these results of the lime dosage/curing time study and the Phase I evaluation, the formulation using lime, fly ash, and cement was selected for final WAC Phase II mix testing and analysis.

The 207C material was tested at specific gravities between 1.50 and 1.98, which correspond to 56.3% and 82.5% solids. The water-to-pozzolan (W/P) ratios were held at 0.2 and 0.3 for both loadings, using a fly ash to cement ratio of 2:1. The amount of lime added was 7.5% by weight of waste feed. The mix performed at S.G = 1.98 (82.5% solids) at a W/P ratio of 0.30 also varied the lime addition from 5% to 10% lime by weight of waste feed. A summary of the mixes performed is provided in Table 2-9.

2.6 CLARIFIER TREATABILITY STUDY TESTING

Testing of clarifier sludge included a baseline analysis of the as received material, friable mix development (pre-WAC mixes), and WAC compliance testing (Phases I and II mixes).

2.6.1 Initial Preparation and Characterization

The clarifier material was delivered to the NUS Pittsburgh Laboratory on December 9, 1994, in a 55-gallon metal drum. Inside the drum was a 30-gallon double-bunghole poly drum and vermiculite packing material. The consistency of the material was of a pudding or brown mud. The material was placed in 5-gallon plastic buckets and submitted for baseline analysis and TCLP analysis. For WAC testing, the material was diluted with 207A/B water to 20% and 30% solids. The as received material is 38.1% solids.

TABLE 2-8

207C WAC PHASE II
CURING TIME AND LIME ADDITION STUDY
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Solids	Specific Gravity	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly ash/ Cement Ratio	Curing Time
1A	03/09/95	70.8	1.75	0.23	5	1 / 0	24 hours
2A	03/09/95	70.8	1.75	0.23	5	1 / 0	48 hours
3A	03/09/95	70.8	1.75	0.23	5	1 / 0	72 hours
4A	03/09/95	70.8	1.75	0.23	5	1 / 0	7 days
1B	03/09/95	70.8	1.75	0.23	10	1 / 0	24 hours
2B	03/09/95	70.8	1.75	0.23	10	1 / 0	48 hours
3B	03/09/95	70.8	1.75	0.23	10	1 / 0	72 hours
4B	03/09/95	70.8	1.75	0.23	10	1 / 0	7 days
1C	03/09/95	70.8	1.75	0.23	15	1 / 0	24 hours
2C	03/09/95	70.8	1.75	0.23	15	1 / 0	48 hours
3C	03/09/95	70.8	1.75	0.23	15	1 / 0	72 hours
4C	03/09/95	70.8	1.75	0.23	15	1 / 0	7 days
1D	03/09/95	70.8	1.75	0.23	5	2 / 1	24 hours
2D	03/09/95	70.8	1.75	0.23	5	2 / 1	48 hours
3D	03/09/95	70.8	1.75	0.23	5	2 / 1	72 hours
4D	03/09/95	70.8	1.75	0.23	5	2 / 1	7 days
1E	03/09/95	70.8	1.75	0.23	10	2 / 1	24 hours
2E	03/09/95	70.8	1.75	0.23	10	2 / 1	48 hours
3E	03/09/95	70.8	1.75	0.23	10	2 / 1	72 hours
4E	03/09/95	70.8	1.75	0.23	10	2 / 1	7 days
1F	03/09/95	70.8	1.75	0.23	15	2 / 1	24 hours
2F	03/09/95	70.8	1.75	0.23	15	2 / 1	48 hours
3F	03/09/95	70.8	1.75	0.23	15	2 / 1	72 hours
4F	03/09/95	70.8	1.75	0.23	15	2 / 1	7 days

TABLE 2-9

SUMMARY OF 207C WAC PHASE II MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Total Solids	Specific Gravity	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly Ash/Cement Ratio
1	03/20/95	56.3	1.5	0.15	7.5	2 / 1
2	03/20/95	56.3	1.5	0.35	7.5	2 / 1
3	03/20/95	82.5	1.98	0.15	7.5	2 / 1
4	03/20/95	82.5	1.98	0.35	5.0	2 / 1
5	03/20/95	82.5	1.98	0.35	7.5	2 / 1
6	03/20/95	82.5	1.98	0.35	10.0	2 / 1

Note: The above mixes were recorded on videotape No. 2 entitled "207C Mixes."

2.6.2 Lime Addition Study

The lime addition study was performed on the clarifier sludge in its "as received" state. Only two lime additives were tested to develop the pH curve. Both hydrated lime and quicklime were added at 3.3% and 16.7% lime by weight. No bacteriological evaluation was performed on this material.

2.6.3 Process Formulation Development

Mixes were performed to develop a process formulation and subsequent process range which achieves the established goals. Mixes performed in the friable mix development phase evaluated a wide range of additives to establish a formulation which provided a friable mix. The mixes performed in the WAC compliance testing phase attempted to establish a process range and evaluated the formulas for WAC acceptance. These phases are discussed in further detail below.

2.6.3.1 Pre-WAC Friable Mix Development

Testing was performed on the clarifier sludge to determine the amount of pozzolan addition required to produce a friable mix. It was determined in the 207A/B and 207C Phase I mixes that hydrated lime, fly ash, silica flour, and cement were the additives which showed the best results. These additives were added in specific amounts to determine the approximate W/P ratio required to achieve the desired product.

2.6.3.2 WAC Compliance Testing

Phase I. The goal of this phase of the treatability study was to evaluate the selected additive combinations, established in the pre-WAC study, for compliance with the waste acceptance criteria and desired final mix consistency. The combination of additives tested included:

- Lime and fly ash
- Lime, fly ash, and silica flour
- Lime, fly ash, and cement

Mixes were performed attempting to establish physical and chemical boundaries for the various mixes. The Clarifier waste material was added at various percent solids, and the amount of pozzolans added were varied in relationship to the amount of water available in the feed waste. Table 2-10 provides a summary of the mixes performed.

TABLE 2-10

SUMMARY OF CLARIFIER PHASE I WAC MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly Ash/Cement/ Silica Flour Ratio
1A	02/03/95	20	0.24	5.0	1 / 0 / 0
2A	02/03/95	20	0.28	5.0	1 / 0 / 0
3A	02/03/95	20	0.34	5.0	1 / 0 / 0
4A	02/03/95	30	0.24	5.0	1 / 0 / 0
5A	02/03/95	30	0.28	5.0	1 / 0 / 0
6A	02/03/95	30	0.34	5.0	1 / 0 / 0
7A	02/03/95	38.1	0.24	5.0	1 / 0 / 0
8A	02/03/95	38.1	0.28	5.0	1 / 0 / 0
9A	02/03/95	38.1	0.34	5.0	1 / 0 / 0
1B	02/07/95	20	0.20	5.0	5.67 / 0 / 1
2B	02/07/95	20	0.25	5.0	5.67 / 0 / 1
3B	02/07/95	20	0.30	5.0	5.67 / 0 / 1
4B	02/07/95	30	0.20	5.0	5.67 / 0 / 1
5B	02/07/95	30	0.25	5.0	5.67 / 0 / 1
6B	02/07/95	30	0.30	5.0	5.67 / 0 / 1
7B	02/07/95	38.1	0.20	5.0	5.67 / 0 / 1
8B	02/07/95	38.1	0.25	5.0	5.67 / 0 / 1
9B	02/07/95	38.1	0.30	5.0	5.67 / 0 / 1
1C	02/06/95	20	0.20	5.0	2 / 1 / 0
2C	02/06/95	20	0.25	5.0	2 / 1 / 0
3C	02/06/95	20	0.30	5.0	2 / 1 / 0
4C	02/06/95	30	0.20	5.0	2 / 1 / 0
5C	02/06/95	30	0.25	5.0	2 / 1 / 0
6C	02/06/95	30	0.30	5.0	2 / 1 / 0
7C	02/06/95	38.1	0.20	5.0	2 / 1 / 0
8C	02/06/95	38.1	0.25	5.0	2 / 1 / 0
9C	02/06/95	38.1	0.30	5.0	2 / 1 / 0

Note: The above mixes were recorded on videotape No. 4 entitled "Clarifier Mixes."

The mixes were prepared in a Hobart mixer on speed setting No. 2, which is an aggressive, higher rpm setting. The additives were added in one bulk addition to the waste feed material (Clarifier at various percent solids) and permitted to mix for 2 minutes and 30 seconds. Observations of the material's consistency were made and video recordings were taken. The final product was then placed in a plastic cylinder mold and plastic bag for curing. After 24 hours the material in the plastic bags was processed through a 3/4-inch-diameter sieve and submitted for TCLP analysis. The cylinders were allowed to cure for 48 hours at which point they were tested for UCS. Based on the physical, analytical and UCS results, a representative mix was selected for final confirmation testing.

Phase II. Based on the results of the WAC Phase I testing, the formulation using lime, fly ash, and cement was selected for final WAC Phase II testing and analysis.

The Clarifier material was tested at solids loadings of 20% and 38.1% solids. The water-to-pozzolan (W/P) ratios were evaluated at 0.2 and 0.3. A fly ash to cement ratio of 2:1 was used. The amount of lime added was 7.5% by weight of waste feed. The mix performed at 38.1% solids and a W/P ratio of 0.30 was also tested at 5% and 10% lime by weight of the feed material. A summary of the mixes performed is provided in Table 2-11.

2.7 207C AND CLARIFIER SLUDGE TREATABILITY STUDY TESTING

Testing of the 207C and Clarifier sludge consisted of preparation of the material and WAC Phase II mixes only. The clarifier sludge was blended with 207C material for testing as a precaution if the clarifier material could not be treated by itself.

2.7.1 Initial Preparation and Characterization

The 207C and Clarifier material was prepared by combining 80% by weight of 207C with 20% by weight of clarifier sludge. Evaluation of the individual components was performed, therefore, a baseline analysis was not necessary. This material was tested only in the Phase II WAC mixes.

2.7.2 Lime Addition Study

No lime addition study was performed on the combined material, since they were tested separately.

TABLE 2-11

SUMMARY OF CLARIFIER PHASE II WAC MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Total Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly Ash/Cement Ratio
1	03/21/95	20	0.20	7.5	2 / 1
2	03/21/95	20	0.30	7.5	2 / 1
3	03/22/95	38.1	0.20	7.5	2 / 1
4	03/22/95	38.1	0.30	5.0	2 / 1
5	03/22/95	38.1	0.30	7.5	2 / 1
6	03/22/95	38.1	0.30	10.0	2 / 1

Note: The above mixes were recorded on videotape No. 4 entitled "Clarifier Mixes."

2.7.3 <u>Process Formulation Development</u>

2.7.3.1 Pre-WAC Friable Mix Development

The development of a friable mix with combined 207C and Clarifier can be determined by evaluation of its individual components. Specific pre-WAC testing was not necessary.

2.7.3.2 WAC Compliance Testing

<u>Phase I</u>. Mixes using combined 207C and Clarifier were not performed in this phase, but were evaluated in Phase II using the selected formulation determined in testing performed on the individual components.

<u>Phase II</u>. The 207C and clarifier blend was tested at 49% solids and 73.6% solids. The water-to-pozzolan (W/P) ratios were tested at 0.16 and 0.30, using a fly ash to cement ratio of 2:1. The amount of lime added was 7.5% by weight of the waste feed. The mix performed at 73.6% solids and 0.30 W/P ratio also varied the lime addition from 5% to 10% lime by weight. A summary of the mixes performed is provided in Table 2-12.

TABLE 2-12

SUMMARY OF 207C AND CLARIFIER PHASE II WAC MIXES
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Total Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Fly Ash/Cement Silica Flour Ratio
1	03/22/95	49	0.16	7.5	2 / 1
2	03/22/95	49	0.30	7.5	2 / 1
3	03/22/95	73.6	0.16	7.5	2 / 1
4	03/22/95	73.6	0.30	5.0	2 / 1
5	03/22/95	73.6	0.30	7.5	2 / 1
6	03/22/95	73.6	0.30	10.0	2 / 1

Note: The above mixes were recorded on videotape No. 4 entitled "Clarifier Mixes."

3.0 RESULTS AND DISCUSSION

This section provides the results of the testing conducted for the pond sludge treatability study. Section 3.1 provides the results of the testing performed on Pond 207A/B (series). Sections 3.2 and 3.3 provide the results of the testing performed on Pond 207C and Clarifier, respectively. The results of testing performed on combined 207C and Clarifier are provided in Section 3.4.

3.1 POND 207A/B (SERIES) RESULTS

Testing performed on Pond 207A/B material included initial characterization, a lime addition study, friable mix development (pre-WAC), waste acceptance criteria compliance (WAC-Phase I), and final evaluation (WAC-Phase II).

3.1.1 Initial Characterization Data

The "as received" 207A/B material was submitted for baseline and TCLP analysis. This information is provided in Table 3-1.

Sample analysis was conducted for selected contaminants determined to be of potential concern when the treated sludge is eventually placed in the OU4 closure. The data show that there are relatively low levels of the analytes in the 207A/B sludge compared to the Clarifier sludge and the Pond 207C waste. It should also be noted that the sludge, as received, was at 63.2% solids (1.54 bulk density), which is abnormally high for this material. The sludge solids were obtained from the vacuum truck used to transfer sludge from the ponds to the storage tanks on the 750 pad, and represent the heavier material that collected in the bottom of the truck. For future testing, this material was diluted with 207A/B pond water to achieve solids concentrations representative of the range expected in the storage tanks.

The TCLP leachate data indicate that uranium isotopes in the untreated sludge would leach at unacceptable levels under worst-case infiltration (1 inch/year) conditions for the OU4 closure, but that the concentrations in the leachate would be acceptable at the estimated design infiltration rate for the OU4 closure (0.0068 inch/year).

TABLE 3-1

SUMMARY OF BASELINE ANALYTICAL RESULTS
207A/B "AS RECEIVED" MATERIAL
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		207A/B Baseline	207A/B TCLP[2]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0297358	P0297359
Date:				01/04/95	01/04/95
W/P:				NA	NA
% Solids:				63.2%	NA
Analyte	Units[1]				
Am-241	pCi/L	17,100	74.5	48 ± 12 pCi/g	0.87 ± 0.51
Cs-134	pCi/L	3,510,000	12,800	< 1 pCi/g	< 5
Cs-137	pCi/L	111,000	737	<1 pCi/g	< 6
Pu-238	pCi/L	NA	NA	0.03 ± 0.02 pCi/g	< 6
Pu-239/240	pCi/L	1,070	4.43	1.6 ± 0.2 pCi/g	< 4
Ra-226	pCi/L	117,000	415	1.1 ± 0.4 pCi/g	1.0 ± 0.4
U-233/234	pCi/L	35,200	254	7.6 ± 0.8 pCi/g	1800 ± 200
U-235	pCi/L	1,410	10.2	0.37 ± 0.07 pCi/g	69 ± 18
U-238	pCi/L	24,500	177	8.6 ± 0.9 pCi/g	2000 ± 200
Strontium 89	pCi/L	NA	NA	<0.3 pCi/g	1.2 ± 0.2
Strontium 90	pCi/L	NA	NA	<0.4 pCi/g	1.2 ± 0.5
Beryllium	mg/L	1.43	0.0142	3.1 mg/kg	<0.0004*
Cadmium	mg/L	5.19	0.0518	32 mg/kg	0.029
pH	Units	NA	NA	9.4	7.2 (Leachate)
Bulk Density	g/cc	NA	NA	1.54	NT

* Result determined by a single point method of standard additions.
NA Not applicable
NT Not tested
(1) Units unless otherwise noted.
(2) TCLP extraction fluid 2.

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

3.1.2 Lime Addition Study Data

The lime addition study for 207A/B sludge was conducted using sludge at 20 percent solids concentration and both hydrated lime [$Ca(OH)_2$] and quicklime (CaO). As described in Section 2.4.2, small dosages of lime were added incrementally to the sludge, and samples were collected for measurement of pH and bacterial standard plate count. As explained in Section 2.4.2, the goal of the study was to determine the dosage required to achieve a pH of 12, which is sufficient to stabilize the sludge from the perspective of reducing the bacterial population present and thus inhibit any future biological degradation of organics in the waste.

Table 3-2 presents standard plate count data. Plots of lime dosage versus pH are presented in Figure 3-1. As shown on Figure 3-1, the addition of both hydrated lime and quicklime result in a fairly rapid rise of pH from an initial pH of 9.4 to greater than 12. Both curves begin to flatten at pH values greater than 12, indicating that the addition of greater dosages of lime result in incrementally lower increases in pH. From an operational standpoint, it is recommended that the treatment systems operate at a point on the curve slightly to the right of the breakpoint. This is at a point where a slight reduction in lime dosage would not result in a rapid decrease in pH, but also at a point where additional dosage of lime would not increase the pH appreciably. The dosages of hydrated lime and quicklime that achieve the stated goals are approximately 4 percent by weight for both types of lime. The data indicate that hydrated lime is slightly more effective than quicklime for treating the 207A/B sludge. The plate count data are less useful in assessing the effectiveness of the pH change in reducing the bacterial plate count due to the relatively low amount of aerobic/facultative bacteria present in the initial sample.

3.1.3 Process Formulation Development Data

The development of the process formulation for treating A/B sludges included three stages of treatability testing; the development of a friable mix (pre-WAC) and the waste acceptance criteria (WAC) compliance testing Phase I and Phase II.

3.1.3.1 Pre-WAC Friable Mix Development

One of the desired properties of the treated sludge is that the material be the consistency of a friable soil while still providing all the benefits of chemical stabilization/solidification (CSS). At the start of the treatability study, it was not known whether a friable material could be achieved. A series of mixes with a wide range of additives, singly and in combination, were prepared for the sole purpose of observing the properties of the treated product. The results of these mixes are summarized in Table 3-3.

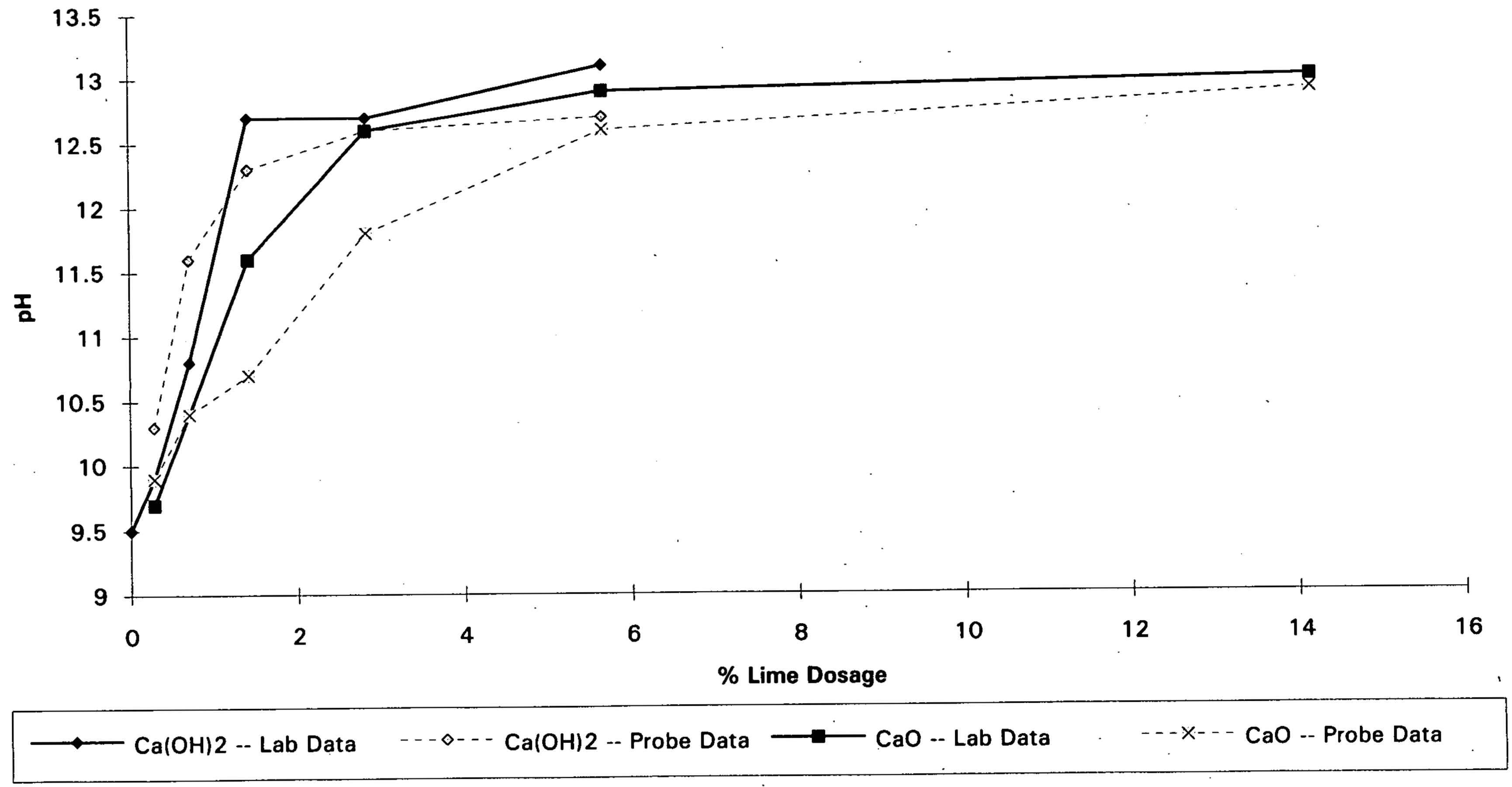
TABLE 3-2

SUMMARY OF PLATE COUNT RESULTS FOR THE LIME ADDITION STUDY
207A/B AT 20 PERCENT SOLIDS
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample Number	Lime Addition (g)	Percent Lime by weight (%)	Type of Lime	Amount of Material (g)	Plate Count
1	0	0	NA	353	<10,000
2	5	1.4	$Ca(OH)_2$	353	<10,000
3	10	2.8	$Ca(OH)_2$	353	<10,000
4	2.5	0.7	$Ca(OH)_2$	353	<10,000
5	20	5.7	$Ca(OH)_2$	353	<10,000
6	1	0.28	$Ca(OH)_2$	353	<10,000
7	1	0.28	CaO	353	55,000
8	2.5	0.7	CaO	353	<10,000
9	5	1.4	CaO	353	<10,000
10	10	2.8	CaO	353	30,000
11	20	5.7	CaO	353	<10,000
12	50	11.4	CaO	353	<10,000
24	0	0	NA	353	<10,000

NA Not applicable, raw sample test, no lime addition.
$Ca(OH)_2$ Hydrated lime
CaO Quicklime

Figure 3-1
Rocky Flats Treatability Study
Lime Addition Study for 207 A/B @ 20% solids
Rocky Flats, Colorado



- Probe Data -- pH check performed in Treatability Lab using field pH instrument
- Lab Data -- pH value received from Inorganic Lab following full QA/QC procedures

LIMEAB.XLC

TABLE 3-3

SUMMARY OF PRE-WAC MIXES, 207A/B SLUDGE
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase		Temperature Increase	Observations
				Not Compacted	Compacted		
1	A/B sludge 294g CaO 350 g	1 1.19	0.67	N/A	N/A	67°F → 206°F after 1.5 hours	A maximum temperature was achieved approximately 1.5 hours after starting to mix CaO. Generated steam. Final mixture was soil-like which turned to fine powder after moisture was released.
2	A/B sludge 294g $Ca(OH)_2$ 450 g	1 1.53	0.52	N/A	N/A	68°F → 70°F	Small curd-size clumps which poured from bowl. Able to pack. The hydrated lime which is in a powder form (not clumpy or chunky like quick lime) mixed with the sludge much better.
3	A/B sludge 294g Fly ash 1200 g	1 4.08	0.20	N/A	N/A	62.3°F → 69.9°F	Medium curd-size clumps, angular in shape, which became hard in the glass jar. Not able to break free from glass jar with finger pressure.
4	A/B sludge 294g Cement 950 g	1 3.23	0.25	N/A	N/A	63°F → 70°F	Produced small pellets which fused in jar. Couldn't break out of jar with finger.
9	A/B sludge 294g CaO* 225g Fly ash 550 g	1 0.77 1.87	0.30	4.4 x	N/A	55.3°F → 63.8°F	Produced small pellets. After 1-day cure, breaks down to powder with slight pressure.

TABLE 3-3 (Continued)
SUMMARY OF PRE-WAC MIXES, 207A/B SLUDGE
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase: Not Compacted	Bulk Volumetric Increase: Compacted	Temperature Increase	Observations
10	A/B sludge 294g CaO* 225g Cement 350 g	1 0.77 1.19	0.41	3.8 x	N/A	55.2°F → 67.8°F	Produced pellets. Pellets remained intact after 1-day cure. Did not fuse together. Some free powder.
11	A/B sludge 294g CaO* 225g CalSeal 300 g	1 0.77 1.02	0.45	3.6 x	N/A	55.4°F → 64.1°F	Produced small pellets. After 1 day, pellets hardened. Material fused somewhat, but was easily broken with finger pressure.
12	A/B sludge 294g CaO* 225g Silica Flour 400 g	1 0.77 1.36	0.38	4 x	N/A	55.6°F → 87.8°F	Produced pea-size pellets. After 24 hours, pellets easily crushed to powder.
13	A/B sludge 294g $Ca(OH)_2$* 100 g Fly ash 850 g	1 0.34 2.89	0.25	4.6 x	N/A	55.2°F → 101°F	Produced hard pea-size pellets. After 1-day cure, pellets remained hard and could be poured out of jar.
14	A/B sludge 294g $Ca(OH)_2$* 100 g Cement 800 g	1 0.34 2.72	0.26	4.4 x	N/A	55.4°F → 62.5°F	Produced pea-size chunks. After 1-day cure, fused into monolith that couldn't be broken by finger pressure.
15	A/B sludge 294g $Ca(OH)_2$* 100 g CalSeal 800 g	1 0.34 2.72	0.26	5 x	N/A	55.1°F → 61.8°F	Produced pellets. After 1-day cure, fused into mass that could be broken with moderate finger pressure.
16	A/B sludge 294g $Ca(OH)_2$* 100 g Silica Flour 800 g	1 0.34 2.72	0.26	5.2 x		55.4°F → 59.6°F	Produced small pellets. Still damp after 1 day. Pellets remained discrete (didn't fuse) and could pour out of jar.
17	A/B sludge 294g Fly ash** 959.5g Silica Flour** 169.2g	1 3.26 0.58	0.21	5.6 x	2.6 x	55.2°F → 65.9°F	Produced large, hard pellets. After 5 hours, fused together into mass, but could break apart with finger pressure.

TABLE 3-3 (Continued)
SUMMARY OF PRE-WAC MIXES, 207A/B SLUDGE
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase		Temperature Increase	Observations
				Not Compacted	Compacted		
18	A/B sludge 294g $Ca(OH)_2$** 230.7g Silica Flour** 691g	1 2.35 0.98	0.26	5 x	2.5 x	55.8°F → 61.3°F	Produced spongy, medium-sized pellets. After 4 hours, fused together into mass, but could be broken apart by fingers.
19	A/B sludge 294g CaO* 275g Cement 250 g	1 0.94 0.85	0.45	3.3 x	1.6 x	58°F → 147°F	Mixture expanding after 3 hours. Friable material which turned to powder with slight finger pressure.
20	A/B sludge 294g CaO* 29g Cement** 375g Fly ash** 750 g	1 0.1 1.28 2.55	0.20	5.6 x	2.8 x	60.2°F → 64.8°F	After 1 hour, still damp. Could not pour out of jar without wing rod.
21	A/B sludge 294g CaO* 150 g Cement** 250 g Fly ash** 500 g	1 0.51 0.85 1.7	0.26	4.6 x	2.3 x	59.2°F → 68.1°F	Uniform large pellets. Feels dry after 1 hour, but still soft. Easily poured from jar.
22	A/B sludge 294 g $Ca(OH)_2$ 29 g Stardust® 1,000 g	1 0.1 3.40	0.23	N/A	N/A	N/A	Formed a wet sandy material not like a friable soil.
23	A/B sludge 294 g $Ca(OH)_2$ 100 g Fly ash 850 g	1 0.34 2.89	0.25	6.7 x	N/A	N/A	This is a re-mix of Mix No. 13. This mix added all additives in one bulk addition. The bulk volume reading is questionable. Formed a powder. Shorter mixing times than Mix No. 13.

TABLE 3-3 (Continued)
SUMMARY OF PRE-WAC MIXES, 207A/B SLUDGE
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		Temperature Increase	Observations
					Not Compacted	Compacted		
24	A/B sludge $Ca(OH)_2$ Fly ash	294 g 100 g 650 g	1 0.34 2.21	0.31	N/A	N/A	N/A	Formed a wet soil. This was considered too wet so added 200 g more flyash to achieve individual pellets or soil clumps. Mixing time played a big part in the consistency of material.
25	A/B sludge $Ca(OH)_2$ Fly ash	294 g 100 g 850 g	1 0.34 2.89	0.25	4 x	N/A	61.3°F → 100°F	This mix was allowed to mix in Hobart on low speed for 30 minutes. After 5 minutes, mixing the material went from powder to a moist soil to pellets after 30 minutes.
26	A/B sludge $Ca(OH)_2$ Fly ash	294 g 100 g 850 g	1 0.34 2.89	0.25	N/A	N/A	N/A	This mix was only allowed to mix for 1.5 minutes and formed a fine powder.
27	A/B sludge $Ca(OH)_2$ Cement Stardust®	294 g 100 g 200 g 950 g	1 0.34 0.68 3.23	0.19	N/A	N/A	N/A	Wet sandy clayish material not forming a friable soil mix.
28	A/B sludge $Ca(OH)_2$ Fly ash	294 g 100 g 850 g	1 0.34 2.89	0.25	N/A	N/A	N/A	This test was designed to see if lime given 15 minutes to react with sludge would provide the desired end product. After 30 minutes achieved a friable soil.

All mixes performed in a Hobart mixer on low speed setting.
*Lime mixed into sludge and allowed to react for 5 minutes before the addition of other additive(s).
**Added as blend.

The results indicated that a friable product could be achieved using a variety of additives. However, relatively low water-to-pozzolan (W/P) ratios (approximately 0.2 to 0.4) were required. This indicates that extra pozzolan is needed to react with the free water in the short mixing time.

While many of the mixes tested achieved a friable product, the potential candidates for WAC compliance testing had to be narrowed to no more than three. The behavior of the final product was used to select the most desirable mixes. Mixes that had excessive temperature increases, that tended to fuse into a monolith after 1-2 days curing (assumed to be representative of the curing/staging time for a full-scale system), or that tended to disaggregate or produce excessive fines, were deemed to be less desirable and were eliminated. For these reasons, mixes of just lime (temperature increase, material turned to dust), just cement (tended to form monolith), and just fly ash (tended to form monolith) were dropped from further consideration.

3.1.3.2 WAC Compliance Testing

Phase I. Based on the results of the pre-WAC testing, three additive combinations were selected. These mixes provided a final material which was the consistency of a friable soil and did not tend to form a monolith after curing. The mix formulas selected include:

- Hydrated lime and fly ash
- Hydrated lime, fly ash, and silica flour
- Hydrated lime, fly ash, and cement

Additional testing was then performed to determine WAC compliance over the anticipated operating ranges for water-to-pozzolan ratios (W/P) and waste loadings. The mixes prepared using lime and fly ash are summarized in Table 3-4. The mixes prepared using lime, fly ash, and silica flour are summarized in Table 3-5. The mixes prepared using lime, fly ash, and cement are summarized in Table 3-6. Two additional mixes were performed to evaluate the addition of hydrated lime only and a mix containing hydrated lime and cement. These mixes are summarized in Table 3-7.

The samples were submitted for Toxicity Characteristic Leaching Procedure (TCLP) and Constituents of Concern (COC) analysis, paint filter liquids test, and bulk density. The results of these analyses are summarized in Table 3-8 for the lime and fly ash mixes. Table 3-9 provides a summary of the analytical results for the lime, fly ash, and silica flour mixes. Table 3-10 provides a summary of the analytical results for the lime, fly ash, and cement mixes. Table 3-11 summarizes the analytical results for the hydrated lime

TABLE 3-4

SUMMARY OF WAC PHASE I MIXES
207A/B SLUDGE (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 113 g 991 g	1 0.38 3.37	0.24	N/A	N/A	408 psi	Heavy pack on sides of bowl. Clumpy clay mix in center of bowl. Final product a clumpy clay. After 5 hours cure: individual clumps which were very hard. GOOD MIX.
2	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 113 g 833 g	1 0.38 2.83	0.28	N/A	N/A	>637 psi	After 30 seconds turned to a friable soil (worm dirt). After 1 minute formed bread dough, then molding clay. After 5 hours cure was a very hard monolith. WET MIX.
3	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 113 g 667 g	1 0.38 2.27	0.34	N/A	N/A	>637 psi	Quickly turned to a friable soil (worm dirt) and after 15 seconds turned to large clay clumps. After 1 minute cookie dough then smooth stiff moist clay. After 5 hours cure became a very hard monolith. WET MIX.
4	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 100 g 900 g	1 0.34 3.06	0.23	5 X	3.7 X	0 psi	After 1 minute of mixing started to clump like a soil and stick to sides of bowl. Resembled moist dirt. After 5 hours cure some hard pea-size clumps mixed in with powder. DRY MIX.
5	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 100 g 750 g	1 0.34 2.55	0.28	4.6 X	2.3 X	228 psi	After 1 minute became a clumpy dirt or soil mix with still some free powder. The material was divided in bowl of packed material on sides of bowl and moist friable soil (worm dirt) in center. After 4 hours cure a friable dirt or dried chunks of soil. GOOD MIX.
6	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 100 g 600 g	1 0.34 2.04	0.34	N/A	N/A	>637 psi	Immediately formed large soil clumps. After 1 minute became a moist molding clay. There was considerable sticking on side of bowl. Final product was a stiff molding clay. After 3 hours cure became a very hard monolith. WET MIX.

TABLE 3-4 (Continued)
SUMMARY OF WAC PHASE I MIXES
207A/B SLUDGE (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
7	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 87 g 771 g	1 0.29 2.62	0.24	5.2 X	3.4 X	0 psi	Immediately became soft pellets or pea-size balls. After one minute broke down to a powder and began to pack on bowl sides. Final product a moist powder. After 2.5 hours cure was a dryish powder. DRY MIX.
8	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 87 g 649 g	1 0.29 2.21	0.28	4.2 X	2.1 X	228 psi	After 1 minute mixing a moist clumpy soil. After 2 minutes 30 seconds of mixing became a medium curd soil (worm dirt). After 2 hours cure, a clumpy dirt mix. GOOD MIX.
9	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C	294 g 87 g 519 g	1 0.29 1.76	0.34	4.2 X	2.7 X	55 psi	Immediately formed pea-size chunks which broke down quickly. Final product formed a moist powder with hard pack on sides of bowl. After 1 hour cure a clump to powder mix. Wide range of particle sizes. GOOD MIX.

N/A Not Available.

TABLE 3-5

SUMMARY OF WAC PHASE I MIXES
207A/B SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1A	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 1126 g 199 g	1 0.05 3.83 0.68	0.20	5.8 X	3.1 X	408 psi	After 1 minute mixing created a small curd friable soil (worm dirt) which quickly became large curd to large soil clumps and a lot of packing on sides of bowl. Final product a clumpy friable clay. GOOD MIX.
2A	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 901 g 159 g	1 0.05 3.06 0.54	0.25	3.3 X	2.4 X	>637 psi	Immediately turned to large clay chunks which turned to a bread dough consistency. After 1 to 1.5 minutes became to a clay to dry clay. Final product after 2.5 minutes a molding clay consistency. WET MIX.
3A	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 751 g 132 g	1 0.05 2.55 0.45	0.30	N/A	2.4 X	>637 psi	After 30 seconds turned to a cake icing consistency. Final product was a smooth wet material. Formed a hard monolith after only couple hours curing. WET MIX.
4A	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 999 g 176 g	1 0.05 3.40 0.60	0.20	5.6 X	3.4 X	254 psi	After 1 minute of mixing began to stick to sides of bowl and form some small soil clumps in the powder. Final product consistency of brown sugar. DRY MIX.
5A	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 799 g 141 g	1 0.05 2.72 0.48	0.25	5 X	2.3 X	>637 psi	Immediately formed large clumps. Some side of bowl packing but pulled off after 2 minutes of mixing. Final product after 2.5 minutes mixing was a medium-size clumps (1"-1.5" diameter). GOOD MIX.
6A	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 665 g 118 g	1 0.05 2.26 0.40	0.30	N/A	2.3 X	>637 psi	Immediately formed a clay ball which turned to the consistency of bread dough then after 2.5 minutes became a molding clay. WET MIX.

TABLE 3-5 (Continued)
SUMMARY OF WAC PHASE I MIXES
207A/B SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
7A	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 875 g 154 g	1 0.05 2.98 0.52	0.20	5.6 X	2.8 X	0 psi	Formed small pea-size clumps in powder which after 1 minute began to pack on sides of bowl. Final consistency of a moist powder. DRY MIX.
8A	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 700 g 129 g	1 0.05 2.38 0.44	0.25	4.6 X	2.8 X	68 psi	After 1 minute mixing mostly powder and some packing on sides of bowl. Final product was a moist powder. DRY MIX.
9A	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Silica Flour	294 g 14.7 g 583 g 103 g	1 0.05 1.98 0.35	0.30	4.2 X	2.1 X	>637 psi	After 30 seconds formed dry pea-size balls with some sticking to sides of bowl. After 1 minute mixing made a friable soil (worm dirt). At end of mixing (2.5 minutes) a lot of material packed on side of bowl and angular soil chunks. GOOD MIX.

N/A - Not available, material too wet to loose pack in cylinder.

TABLE 3-6

SUMMARY OF WAC PHASE I MIXES
207A/B SLUDGE (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1B	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 883 g 442 g	1 0.05 3.00 1.50	0.20	6.4 X	3.9 X	262 psi	After 1 minute mixing, consistency of moist powder. Material stayed like this until stopped mixing. After 5 hours curing was a dry to semi-moist fine powder. DRY MIX.
2B	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 707 g 353 g	1 0.05 2.40 1.20	0.25	N/A	2.4 X	>637 psi	Immediately turned to large clay clumps, then to bread dough. After 1 minute, was consistency of sticky cake icing. After 2.5-minute mixing, was consistency of fudge or a stiff clay. After 5-hour cure, made a hard monolith. WET MIX.
3B	A/B sludge @ 10% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 589 g 294 g	1 0.05 2.00 1.00	0.30	N/A	2.4 X	>637 psi	Immediately made large clay clumps, but turned to a cake icing after 1.5 minutes mixing. Final mix after 2.5 minutes mixing was a smooth clay or stiff mud. After 5-hour cure, formed a hard monolith. WET MIX.
4B	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 783 g 392 g	1 0.05 2.66 1.33	0.20	5.8 X	3.9 X	0 psi	Mix was consistency of a moist soil or powder. Final product moist powder. After 4-hour cure, made a fine powder mix. DRY MIX.
5B	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 627 g 313 g	1 0.05 2.13 1.06	0.25	5 X	2.5 X	395 psi	This mix had two distinct consistencies, a hard side of bowl packing and the center a moist powder. Final product a moist powder. After 3-hour cure, consistency of a moist dirt mix. DRY MIX.
6B	A/B sludge @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 522 g 261 g	1 0.05 1.77 0.89	0.30	N/A	2.3 X	>637 psi	Immediately formed large moist clumps and was an excellent friable soil (worm dirt), of medium-size clumps. Friable soil after 30 seconds. Final product was a stiff molding clay. After curing for 3 hours was still moldable, but crushed under hand pressure. GOOD MIX.

TABLE 3-6 (Continued)
SUMMARY OF WAC PHASE I MIXES
207A/B SLUDGE (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
7B	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 687 g 343 g	1 0.05 2.34 1.17	0.20	5.1 X	3.4 X	163 psi	Immediately formed pellets which turned into a fine dry powder after 1 minute. Final product a moist powder. After 2-hour cure, still a fine powder. DRY MIX.
8B	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 549 g 275 g	1 0.05 1.87 0.93	0.25	4.2 X	2.8 X	108 psi	Final product was a moist powder with some side of bowl packing. After 2-hour cure, still a fine powder consistency of brown sugar. DRY MIX.
9B	A/B sludge @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	294 g 14.7 g 458 g 229 g	1 0.05 1.56 0.78	0.30	3.6 X	1.8 X	222 psi	After 1 minute of mixing had a hard dirt pack on sides of bowl, with center resembling a moist soil. Final product a moist soil. After 1-hour cure, looked like potting soil. GOOD MIX.

TABLE 3-7

SUMMARY OF WAC PHASE I MIXES
207A/B SLUDGE (ADDITIONAL MIXES)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1C	A/B sludge @ 20% solids $Ca(OH)_2$	294 g 298 g	1 1.35	0.59	3.8 X	2.6 X	0 psi	Heavy pack on sides of bowl and powder in center. Final product a dry powder. DRY MIX.
2C	A/B sludge @ 20% Solids $Ca(OH)_2$ Cement, Type I/II	294 g 14.7 g 758 g	1 0.05 2.58	0.31	4 X	2.2 X	351 psi	Moist soil with some small clumps. Final product after mixing (2.5 minutes) consistency of brown sugar. DRY MIX.

TABLE 3-8

WAC PHASE I ANALYTICAL RESULTS
207A/B MIXES (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1-207A/B	#2-207A/B	#3-207A/B	#4-207A/B	#5-207A/B	#6-207A/B	#7-207A/B	#8-207A/B	#9-207A/B	1Dup-207A/B[1]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0299756 P0299757	P0299758	P0299759 P0299760	P0299761 P0299762	P0299763	P0299764 P0299765	P0299766 P0299767	P0299768	P0299769 P0299770	P0301413
Date:				01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	02/17/95
W/P:				0.24	0.28	0.34	0.24	0.28	0.34	0.24	0.28	0.34	0.24
% Solids:				10	10	10	20	20	20	30	30	30	20
Analyte	Units												
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-134	pCi/L	3,510,000	12,800	< 4	NS	< 3	< 5	NS	< 4	< 4	NS	< 6	<4
Cs-137	pCi/L	111,000	737	< 5	NS	< 3	< 7	NS	< 5	< 4	NS	< 7	<4
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Ra-226	pCi/L	117,000	415	0.4 ± 0.1	NS	0.4 ± 0.1	<0.2	NS	0.4 ± 0.3	<0.2	NS	<0.5	1.4 ± 0.2
U-233/234	pCi/L	35,200	254	0.20 ± -0.05	NS	0.039 ± .021	11 ± 2	NS	0.13 ± .04	60 ± 6	NS	78 ± 14	0.08 ± 0.01
U-235	pCi/L	1,410	10.2	<0.03	NS	0.021 ± .015	0.69 ± 0.12	NS	0.035 ± .022	3.1 ± 0.4	NS	< 1.5	<0.03
U-238	pCi/L	24,500	177	0.16 ± 0.05	NS	0.024 ± .017	12 ± 2	NS	0.07 ± .03	67 ± 7	NS	100 ± 17	0.10 ± 0.01
Arsenic	mg/L	13.6	0.142	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Beryllium	mg/L	1.43	0.0142	<0.0005	NS	<0.0005	<0.0005	NS	<0.0005	<0.0005	NS	<0.0005	<0.0005
Cadmium	mg/L	5.19	0.0518	<0.005	NS	<0.005	<0.005	NS	<0.005	<0.005	NS	<0.005	<0.005
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Nitrate/Nitrite	mg/L	15,900	166	6.9	NS	7.9	6.9	NS	6.9	5.8	NS	11[2]	3.3
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2	2	NS	2	2
Final Leachate pH	Units	NA	NA	9.2	NS	10.6	9.1	NS	10.2	6.0	NS	6.0	10.9

TABLE 3-8 (Continued)
WAC PHASE I ANALYTICAL RESULTS
207A/B MIXES (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		#1-207A/B	#2-207A/B	#3-207A/B	#4-207A/B	#5-207A/B	#6-207A/B	#7-207A/B	#8-207A/B	#9-207A/B	1Dup-207A/B(1)
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0299756 P0299757	P0299758	P0299759 P0299760	P0299761 P0299762	P0299763	P0299764 P0299765	P0299766 P0299767	P0299768	P0299769 P0299770	P0301413
	Date:			01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	01/30/95	02/17/95
	W/P:			0.24	0.28	0.34	0.24	0.28	0.34	0.24	0.28	0.34	0.24
	% Solids:			10	10	10	20	20	20	30	30	30	20
Analyte	Units												
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0	NA
Bulk Density	g/cc	NA	NA	1.04(3)	1.25	1.19	1.06(4)	1.04	1.16	1.01	0.96	1.05	NA

(1) Field duplicate mix of 013095-4-207A/B; P299762
(2) Sample exceeded holding time
(3) Compacted density = 1.18 g/cc
(4) Compacted Density = 1.44 g/cc

NA Not applicable
NS Not submitted for analysis
NT Not tested for this analyte

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

TABLE 3-9

WAC PHASE I ANALYTICAL RESULTS
207A/B MIXES (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1A-207A/B	#2A-207A/B	#3A-207A/B	#4A-207A/B	#5A-207A/B	#6A-207A/B	#7A-207A/B	#8A-207A/B	#9A-207A/B	2Dup-207A/B[1]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0299925 P0299926	P0299927	P0299928 P0299929	P0299930 P0299931	P0299932	P0299933 P0299934	P0299935 P0299936	P0299937	P0299938 P0299939	P0301414
Date:				01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	02/16/95
W/P:				0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30	0.20
% Solids:				10	10	10	20	20	20	30	30	30	20
Analyte	Units			(1)									
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-134	pCi/L	3,510,000	12,800	< 4	NS	< 3	< 6	NS	< 5	< 3	NS	< 6	< 7
Cs-137	pCi/L	111,000	737	< 5	NS	< 4	< 7	NS	< 5	< 4	NS	< 7	< 7
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Ra-226	pCi/L	117,000	415	0.3 ± 0.1	NS	<0.1	0.9 ± 0.1	NS	0.5 ± 0.1	<0.1	NS	<0.2	0.2 ± 0.1
U-233/234	pCi/L	35,200	254	5.3 ± 0.6	NS	3.3 ± 0.4	2.7 ± 0.3	NS	17 ± 2	18 ± 2	NS	82 ± 9	0.37 ± 0.13
U-235	pCi/L	1,410	10.2	0.25 ± 0.06	NS	0.15 ± 0.02	0.13 ± 0.04	NS	0.89 ± 0.13	1.1 ± 0.2	NS	4.2 ± 0.5	<0.03
U-238	pCi/L	24,500	177	5.8 ± 0.6	NS	2.6 ± 0.3	3.2 ± 0.4	NS	19 ± 2	20 ± 2	NS	93 ± 10	0.38 ± 0.13
Arsenic	mg/L	13.6	0.142	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Beryllium	mg/L	1.43	0.0142	<0.0005	NS	<0.0005	<0.0006*	NS	<0.0006*	<0.0005	NS	<0.0005	<0.0006*
Cadmium	mg/L	5.19	0.0518	<0.005	NS	<0.005	<0.005	NS	<0.005	<0.005	NS	<0.005	<0.005
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Nitrate/Nitrite	mg/L	15,900	166	6.0	NS	12	6.1	NS	14	11	NS	12	5.8
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2	2	NS	2	2
Final Leachate pH	Units	NA	NA	9.0	NS	9.2	9.3	NS	8.9	9.1	NS	8.5	9.4

TABLE 3-9 (Continued)
WAC PHASE I ANALYTICAL RESULTS
207A/B MIXES (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1A-207A/B	#2A-207A/B	#3A-207A/B	#4A-207A/B	#5A-207A/B	#6A-207A/B	#7A-207A/B	#8A-207A/B	#9A-207A/B	2Dup-207A/B[1]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0299925 P0299926	P0299927	P0299928 P0299929	P0299930 P0299931	P0299932	P0299933 P0299934	P0299935 P0299936	P0299937	P0299938 P0299939	P0301414
Date:				01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	01/31/95	02/16/95
W/P:				0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30	0.20
% Solids:				10	10	10	20	20	20	30	30	30	20
Analyte	Units												
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0	NA
Bulk Density	g/cc	NA	NA	1.31	1.30	1.31	1.11	1.29	1.28	1.12	1.12	1.24	NA

[1] Field duplicate of mix 013195-4A-207A/B; P0299931
* Result determined by a single-point method of standard additions.

NA Not applicable
NS Not submitted for analysis
NT Not tested for this analyte

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

TABLE 3-10

WAC PHASE I ANALYTICAL RESULTS
207A/B MIXES (ADDITIVES: LIME, FLY ASH, AND TYPE CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1B-207A/B	#2B-207A/B	#3B-207A/B	#4B-207A/B	#5B-207A/B	#6B-207A/B	#7B-207A/B	#8B-207A/B	#9B-207A/B	3Dup-207A/B[1]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0299969 P0299970	P0299971	P0299972 P0299973	P0299974 P0299975	P0299976	P0299977 P0299978	P0299979 P0299980	P0299981	P0299982 P0299983	P0301415
Date:				02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/17/95
W/P:				0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30	0.20
% Solids:				10	10	10	20	20	20	20	30	30	20
Analyte	Units												
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-134	pCi/L	3,510,000	12,800	< 5	NS	< 7	< 6	NS	< 6	< 5	NS	< 5	< 4
Cs-137	pCi/L	111,000	737	< 6	NS	< 7	< 7	NS	3.6 ± 1.9	< 6	NS	< 6	< 4
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Ra-226	pCi/L	117,000	415	<0.2	NS	<0.2	0.6 ± 0.1	NS	0.2 ± 0.1	0.3 ± 0.1	NS	0.5 ± 0.1	<0.2
U-233/234	pCi/L	35,200	254	7.0 ± 0.7	NS	56 ± 6	2.8 ± 0.3	NS	130 ± 20	12 ± 0.8	NS	280 ± 40	0.051±0.045
U-235	pCi/L	1,410	10.2	0.45 ± 0.08	NS	3.1 ± 0.4	0.20 ± 0.02	NS	6.9 ± 3.9	0.44 ± 0.08	NS	< 8	<0.08
U-238	pCi/L	24,500	177	7.8 ± 0.8	NS	63 ± 7	3.1 ± 0.4	NS	140 ± 20	14 ± 0.9	NS	250 ± 40	0.071±0.053
Arsenic	mg/L	13.6	0.142	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Beryllium	mg/L	1.43	0.0142	<0.0006*	NS	<0.0006*	<0.0007*	NS	<0.0008*	<0.0007*	NS	<0.0008*	<0.0005
Cadmium	mg/L	5.19	0.0518	<0.005	NS	<0.006	<0.005	NS	<0.005	<0.005	NS	<0.005	<0.005
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Nitrate/Nitrite	mg/L	15,900	166	12	NS	12	11	NS	13	12	NS	21	3.9
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2	2	NS	2	2
Final Leachate pH	Units	NA	NA	9.0	NS	7.9	9.2	NS	7.4	9.0	NS	7.6	11.1

TABLE 3-10 (Continued)
WAC PHASE I ANALYTICAL RESULTS
207A/B MIXES (ADDITIVES: LIME, FLY ASH, AND TYPE CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1B-207A/B	#2B-207A/B	#3B-207A/B	#4B-207A/B	#5B-207A/B	#6B-207A/B	#7B-207A/B	#8B-207A/B	#9B-207A/B	3Dup-207A/B(1)
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0299969 P0299970	P0299971	P0299972 P0299973	P0299974 P0299975	P0299976	P0299977 P0299978	P0299979 P0299980	P0299981	P0299982 P0299983	P0301415
Date:				02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/01/95	02/17/95
W/P:				0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30	0.20
% Solids:				10	10	10	20	20	20	20	30	30	20
Analyte	Units												
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0	NA
Bulk Density	g/cc	NA	NA	1.06	1.33	1.30	1.12	1.11	1.30	1.11	1.08	1.10	NA

(1) Field duplicate of mix 020195-4B-207A/B; P0299975
* Result determined by a single-point method of standard additions.
NA Not applicable
NS Not submitted for analyses
NT Not tested for this analyte
Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

TABLE 3-11

SUMMARY OF ANALYTICAL RESULTS, WAC PHASE I 207A/B MIXES (ADDITIONAL MIXES)[1] POND SLUDGE TREATABILITY STUDY ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1C-207A/B	#2C-207A/B
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0300088 P0300089	P0300090 P0300091
Date:				02/02/95	02/02/95
W/P:				0.59	0.31
% Solids:				20%	20%
Analyte	Units				
Am-241	pCi/L	17,100	74.5	NT	NT
Cs-134	pCi/L	3,510,000	12,800	< 5	< 5
Cs-137	pCi/L	111,000	737	< 5	< 6
Pu-239/240	pCi/L	1,070	4.43	NT	NT
Ra-226	pCi/L	117,000	415	9.1 ± 1.0	0.9 ± 0.1
U-233/234	pCi/L	35,200	254	0.49 ± 0.14	133 ± 15
U-235	pCi/L	1,410	10.2	<0.08	4.9 ± 0.9
U-238	pCi/L	24,500	177	0.41 ± 0.13	150 ± 17
Arsenic	mg/L	13.6	0.142	NT	NT
Beryllium	mg/L	1.43	0.0142	< 0.0006*	< 0.0006*
Cadmium	mg/L	5.19	0.0518	< 0.005	< 0.005
Chromium	mg/L	142	0.881	NT	NT
Sodium	mg/L	1,750	14.9	NT	NT
Nitrate/Nitrite	mg/L	15,900	166	17	14
TCLP Extraction Fluid	NA	NA	NA	2	2
Final Leachate pH	Units	NA	NA	11.7	7.4
Paint Filter Liquids Test	mL	NA	NA	0	0
Bulk Density	g/cc	NA	NA	0.74	1.13

(1) Mix #1C; $Ca(OH)_2$ only
Mix #2C; $Ca(OH)_2$ and Type I/II cement
NA - Not applicable
* - Result determined by a single-point method of standard additions.
NT - Not tested for this analyte
Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

only and hydrated lime with cement. The TCLP leachate data were plotted against pH and are provided in Appendix G.

The data provided on Tables 3-8 through 3-11 indicate that some of the analytes are leachable under certain conditions. The graphs of TCLP extract pH versus leachate concentration, in Appendix G, are useful for determining the relationship between pH and leachate concentration. The isotopic uranium data shows that as the TCLP extract pH drops below 9, the concentration in the leachate increases. This trend is not evident for the other analytes, probably because of the low initial concentrations in the 207A/B sludge. The nitrate concentration showed no dependence on pH, as expected.

Phase II. A series of mixes was performed to evaluate the relationship between lime dosage, curing time, and leachate pH to try to correct the variability of TCLP extract pH shown in Phase I. Based on the Phase I data for all the sludges, it was evident that the leachability of the metals and radionuclides could be greatly reduced by controlling the pH of the TCLP extract. The test matrix evaluated three lime dosages and four curing times to determine the effect of these variables on the TCLP extract pH. The pH data are summarized on Table 3-12. The results show that the desired pH can be obtained, even with only a one day curing time. Beryllium and cadmium were selected as surrogate analytes for this test, and all sample results were below detection limits (see data in Appendix F).

Phase II WAC compliance tests were required to demonstrate compliance with the leachability criteria which was not consistently demonstrated during Phase I. For the Phase II WAC compliance tests, the lime, cement, and fly ash additive combination was selected as the preferred formulation. The lime, cement, and fly ash mixture consistently resulted in higher pH compared to the lime and fly ash mixture which is more favorable for reducing leachate concentrations. Based on the Phase I results the silica flour and fly ash formulation offered no advantage compared to the lime, cement, and fly ash formulation. In addition, the lime, cement, and fly ash formulation has been demonstrated to be successful in previous treatability studies with the 207A/B material (HNUS 1992c).

Phase II involved a series of tests that were performed at the high and low W/P ratios identified from Phase I with different lime dosages to test compliance with leachability criteria. A summary of the mixes performed using lime, fly ash, and cement is provided in Table 3-13. The analytical results are provided in Table 3-14, and the graphs plotting TCLP extract concentrations versus extract pH are provided in Appendix G.

The TCLP leachate results provided in Table 3-14 for the 207A/B waste are compared to the WACs. Two WACs are shown on Table 3-14, one is associated with the design infiltration rate of 0.0068 inches per year

TABLE 3-12

SUMMARY OF LEACHATE pH FOR HYDRATED LIME DOSAGE TEST
207A/B WAC PHASE II TESTING
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Additives	Lime Addition	24-Hour Cure pH	48-Hour Cure pH	72-Hour Cure pH	7-Day Cure pH
Lime and Fly Ash	5%	9.9	9.8	8.8	9.9
Lime and Fly Ash	10%	10.0	9.9	10.0	10.0
Lime and Fly Ash	15%	10.4	10.2	10.4	10.3
Lime, Fly Ash, and Cement	5%	11.5	11.2	11.3	11.0
Lime, Fly Ash, and Cement	10%	11.4	11.2	11.3	11.1
Lime, Fly Ash, and Cement	15%	11.6	11.2	11.4	11.1

TABLE 3-13

SUMMARY OF WAC PHASE II MIXES
207A/B SLUDGE (ADDITIVES LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P
1	A/B Sludge @ 10% Solids	294 g	1.0	0.2
	$Ca(OH)_2$	22.1 g	0.075	
	Fly Ash, Type C	882 g	3.0	
	Cement, Type I/II	441 g	1.5	
2	A/B Sludge @ 10% Solids	294 g	1.0	0.3
	$Ca(OH)_2$	22.1 g	0.075	
	Fly Ash, Type C	588 g	2.0	
	Cement, Type I/II	294 g	1.0	
3	A/B Sludge @ 30% Solids	294 g	1.0	0.2
	$Ca(OH)_2$	22.1 g	0.075	
	Fly Ash, Type C	686 g	2.33	
	Cement, Type I/II	343 g	1.17	
4	A/B Sludge @ 30% Solids	294 g	1.0	0.3
	$Ca(OH)_2$	14.7 g	0.05	
	Fly Ash, Type C	457 g	1.55	
	Cement, Type I/II	229 g	0.78	
5	A/B Sludge @ 30% Solids	294 g	1.0	0.3
	$Ca(OH)_2$	22.1 g	0.075	
	Fly Ash, Type C	457 g	1.55	
	Cement, Type I/II	229 g	0.78	
6	A/B Sludge @ 30% Solids	294 g	1.0	0.3
	$Ca(OH)_2$	29.4 g	0.10	
	Fly Ash, Type C	457 g	1.55	
	Cement, Type I/II	229 g	0.78	

TABLE 3-14

SUMMARY OF ANALYTICAL RESULTS, WAC PHASE II
207A/B (LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1-207A/B	#2-207A/B	#3-207A/B	#4-207A/B	#5-207A/B	#6-207A/B
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0304225 P0304226	P0304227 P0304228	P0304229 P0304230	P0304231 P0304232	P0304309 P0304310	P0304311 P0304312
Date:				03/20/95	03/20/95	03/20/95	03/20/95	03/21/95	03/21/95
W/P:				0.20	0.30	0.20	0.30	0.30	0.30
% Solids:				10	10	30	30	30	30
Analyte	Units								
Am-241	pCi/L	17,100	74.5	0.14 ± 0.08	0.035 ± 0.04	< 0.47	< 0.083	< 0.45	< 0.29
Cs-134	pCi/L	3,510,000	12,800	< 6	< 6	< 3	< 5	< 6	< 6
Cs-137	pCi/L	111,000	737	< 7	< 6	< 4	< 5	< 6	< 7
Pu-238	pCi/L	NA	NA	< 0.2	< 0.2	< 0.03	< 0.08	< 0.03	< 0.03
Pu-239/240	pCi/L	1,070	4.43	0.032 ± 0.036	< 0.03	< 0.03	< 0.1	< 0.03	< 0.08
Ra-226	pCi/L	117,000	415	< 0.2	0.3 ± 0.1	0.9 ± 0.1	0.2 ± 0.1	< 0.2	< 0.2
U-233/234	pCi/L	35,200	254	< 0.03	< 0.09	< 0.08	0.044 ± 0.043	< 0.03	< 0.09
U-235	pCi/L	1,410	10.2	< 0.03	< 0.2	< 0.08	< 0.03	< 0.08	< 0.04
U-238	pCi/L	24,500	177	< 0.08	< 0.2	0.044 ± 0.043	0.055 ± 0.048	< 0.08	0.070 ± 0.056
Beryllium	mg/L	1.43	0.0142	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Cadmium	mg/L	5.19	0.0518	<0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005
Arsenic	mg/L	13.6	0.142	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Chromium	mg/L	142	0.881	0.12	0.08	0.18	0.13	0.11	0.13

TABLE 3-14 (Continued)
SUMMARY OF ANALYTICAL RESULTS, WAC PHASE II
207A/B (LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		#1-207A/B	#2-207A/B	#3-207A/B	#4-207A/B	#5-207A/B	#6-207A/B
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0304225 P0304226	P0304227 P0304228	P0304229 P0304230	P0304231 P0304232	P0304309 P0304310	P0304311 P0304312
	Date:			03/20/95	03/20/95	03/20/95	03/20/95	03/21/95	03/21/95
	W/P:			0.20	0.30	0.20	0.30	0.30	0.30
	% Solids:			10	10	30	30	30	30
Analyte	Units								
Nitrate/Nitrite	mg/L	15,900	166	5.7	7.0	3.9	56	< 0.1	4.8
Sodium	mg/L	1,750	14.9	180	160	190	220	240	260
Lead	mg/L	NA	NA	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	<0.05
Nickel	mg/L	NA	NA	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
TCLP Extraction Fluid	N/A	NA	NA	2	2	2	2	2	2
Final Leachate pH	Units	NA	NA	10.9	11.2	11.8	11.2	11.4	11.5
Paint Filter Liquids Test	mL	0	0	0	0	0	0	0	0

NA - Not applicable

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

and the other is associated with a one inch per year infiltration rate. The development of the WACs are discussed in Appendix B.

All analytes leached at concentrations less than the design WAC concentrations. All analytes also leached at concentrations less than the one inch per year WAC concentrations with the exception of sodium. Sodium leached in all of the mixes at concentrations in excess of the WAC and ranged from 160 mg/l to 260 mg/l.

The figures provided in Appendix G indicate that the increase in the lime dosage from 5 percent to 7.5 percent resulted in an increase in the TCLP leachate pH. The pH of the leachate for the Phase II mixes ranged from 10.9 to 11.8 S.U. as shown on Figure G-2A. Minimal relationship between TCLP leachate pH and concentrations of contaminants can be distinguished from the figures shown in Appendix G. This observation is because of the low initial concentrations in the 207A/B waste and the high pH in the TCLP leachate, which resulted in concentrations near detection limits in the leachate. Nitrate/nitrite and sodium leachate concentrations show no dependency on pH.

As shown on Table 3-14, the TCLP extract for Phase II lime, cement, and fly ash mixes were analyzed for lead and nickel, which are LDR constituents associated with the hazardous waste codes for A/B sludge. All LDR metals, including cadmium and chromium, leached at levels below their respective LDR standards.

3.2 PONDS 207C RESULTS

Testing performed on Pond 207C material included an initial characterization, a lime addition study, friable mix development (pre-WAC), waste acceptance criteria compliance evaluation (WAC Phase I); and final acceptance (WAC Phase II).

3.2.1 Initial Characterization Data

The "as received" Pond 207C material was submitted for baseline (TCLP and COC) analyses of the raw material. This information is provided in Table 3-15.

Sample analysis was conducted for selected contaminants determined to be of potential concern when the treated sludge is eventually placed in the OU4 closure. The 207C waste was received at a specific gravity of 2.01 and was diluted with 207A/B pond water to a specific gravity of 1.7, which is the expected maximum value for the waste in the storage tanks. All testing was conducted on 207C waste with a specific gravity of 1.7. The data show that there are higher levels of the analytes in the 207C sludge compared to the

TABLE 3-15

SUMMARY OF BASELINE ANALYTICAL RESULTS
207C MATERIAL (1.7 SPECIFIC GRAVITY)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		207C @ 1.7 SG. Baseline	207C @ 1.7 SG.[3] TCLP
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0297356	P0297357
Date:				01/04/95	01/04/95
W/P:				NA	NA
% Solids:				80.7%[1]	NA
Analyte	Units[2]				
Am-241	pCi/L	17,100	74.5	160 ± 40 pCi/g	460 ± 50
Cs-134	pCi/L	3,510,000	12,800	< 1 pCi/g	< 4
Cs-137	pCi/L	111,000	737	< 1 pCi/g	12 ± 2
Pu-238	pCi/L	NA	NA	0.23 ± 0.03 pCi/g	< 8
Pu-239/240	pCi/L	1,070	4.43	9.6 ± 1 pCi/g	99 ± 17
Ra-226	pCi/L	117,000	415	0.4 ± 0.2 pCi/g	1.7 ± 0.5
U-233/234	pCi/L	35,200	254	4.0 ± 0.4 pCi/g	1100 ± 200
U-235	pCi/L	1,410	10.2	0.22 ± 0.05 pCi/g	73 ± 8
U-238	pCi/L	24,500	177	6.1 ± 0.1 pCi/g	1700 ± 200
Strontium 89	pCi/L	NA	NA	< 0.3 pCi/g	NT
Strontium 90	pCi/L	NA	NA	< 0.3 pCi/g	NT
Beryllium	mg/L	1.43	0.0142	1.9 mg/kg	0.062
Cadmium	mg/L	5.19	0.0518	9.4 mg/kg	0.31
pH	Units	NA	NA	9.7	4.5 (leachate)
Bulk Density	g/cc	NA	NA	1.85	NA

(1) Dissolved solids = 780,000 mg/L, suspended solids = 31,000 mg/L, sample filtered at room temperature (approximately 68°F).
(2) Units unless otherwise noted
(3) TCLP extraction fluid 2
NT Not tested for this analyte
NA Not applicable
Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

207A/B sludge and lower than the Clarifier sludge. The dissolved solids and the suspended solids were determined to be 786,000 mg/l and 31,000 mg/l, respectively.

A sample of the 207C material was tested using TCLP to determine the leachability of the as received material. The results indicate that americium 241, plutonium 239/240, the uranium isotopes, beryllium, and cadmium leached at concentrations above the WAC associated with a 1 inch per year infiltration rate, which represents a future worst-case scenario. None of the constituents leach at concentrations that exceed the WAC associated with the design infiltration rate.

3.2.2 Lime Addition Study Data

The lime addition study for 207C material was conducted using a sample of brine/crystal/sludge diluted to a specific gravity of approximately 1.7, which is the maximum specific gravity of 207C material stored in the tanks on the 750 pad. As described in Section 2.4.3, hydrated lime [$Ca(OH)_2$] and quicklime (CaO) were added incrementally in small doses to the 207C material, and samples were collected for measurement of pH and bacterial standard plate count. As explained in Section 2.4.3, the goal of the study was to determine the dosage of lime required to achieve a pH of 12, which is sufficient to stabilize the sludge from the perspective of reducing the bacterial population present and thus inhibit any future biological degradation of organics present in the waste.

Table 3-16 presents bacterial plate count data. Plots of lime dosage versus pH are presented in Figure 3-2. As can be seen by the data plotted on Figure 3-2, the addition of both hydrated lime and quicklime results in the rapid rise from the initial pH of 10.1 to pH values greater than 12. The breakpoints occurred at a pH of approximately 13.4 for CaO and at a pH of approximately 12.7 for $Ca(OH)_2$. Again, it is recommended that the process operate to the right of the breakpoint on the curve so that any variations in the dosage will have minor effects on the pH. The lime dosages that achieve the stated goals are approximately 5 percent for both hydrated lime and quicklime. Quicklime is somewhat more effective for treating the 207C material, which is the opposite of the observed effectiveness for treating the 207A/B sludge.

The standard plate count data are less useful for evaluating the effectiveness of increased pH in reducing the bacterial count because of the low plate count of aerobic and facultative bacteria observed in the untreated sample.

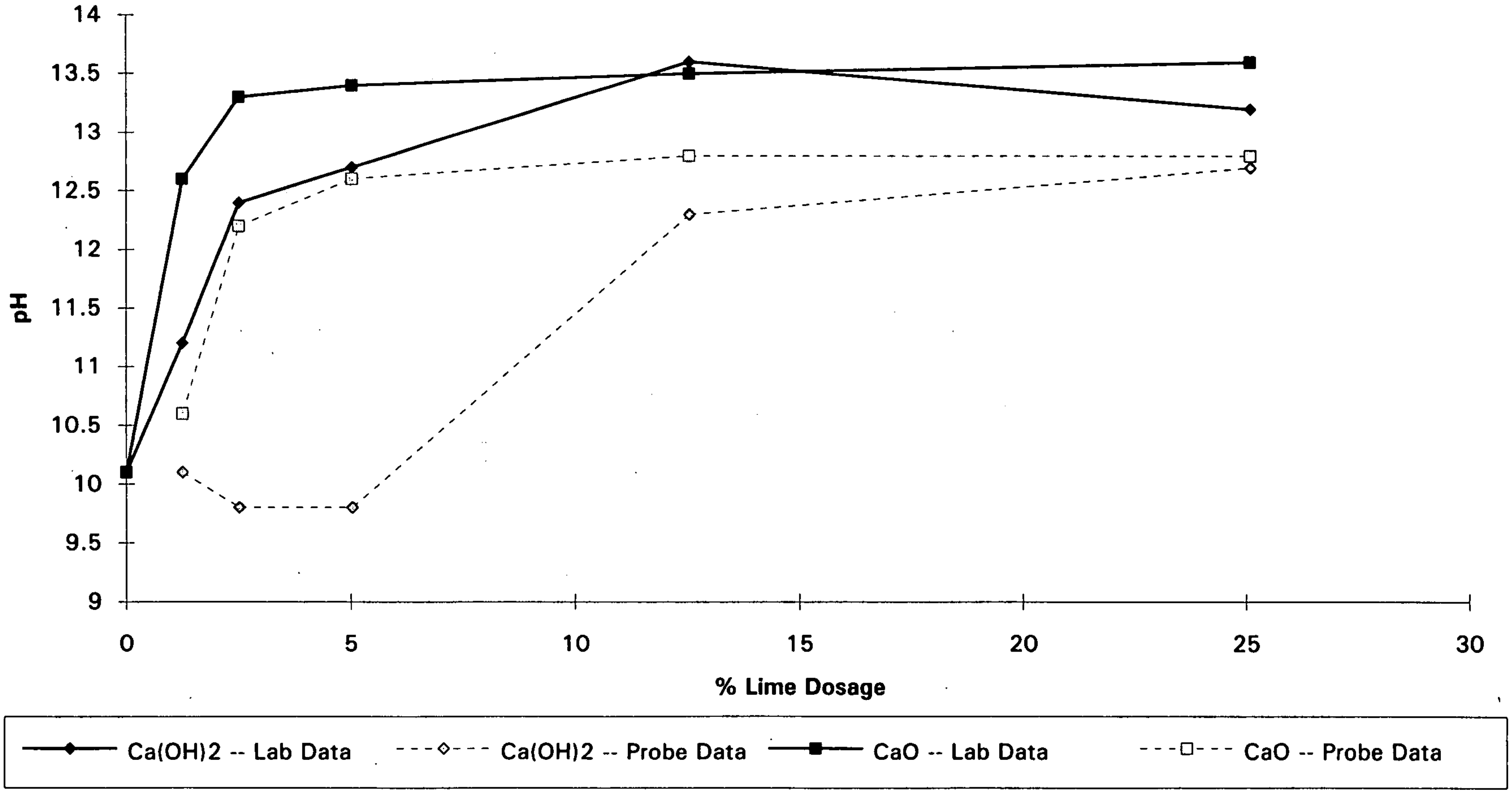
TABLE 3-16

SUMMARY OF BACTERIOLOGY RESULTS FOR THE LIME ADDITION STUDY
207C MATERIAL (1.7 SPECIFIC GRAVITY)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample Number	Lime Addition (g)	Percent Lime Addition by Weight (%)	Type of Lime	Amount of Material (g)	Plate Count	Plate Count (Duplicate)
13	0	0	NA	398	1000	< 1000
14	5	1.2	$Ca(OH)_2$	398	1000	2000
15	10	2.5	$Ca(OH)_2$	398	1000	< 1000
16	20	5.0	$Ca(OH)_2$	398	<1000	< 1000
17	50	12.6	$Ca(OH)_2$	398	<1000	< 1000
18	100	25.1	$Ca(OH)_2$	398	<1000	< 1000
19	5	1.2	CaO	398	<1000	< 1000
20	10	2.5	CaO	398	<1000	< 1000
21	20	5.0	CaO	398	1000	< 1000
22	50	12.6	CaO	398	<1000	< 1000
23	100	25.1	CaO	398	1000	< 1000

NA Not applicable, no lime added.

Figure 3-2
Rocky Flats Treatability Study
Lime Addition Study for 207 C @ 1.7 Specific Gravity
Rocky Flats, Colorado



- Probe Data -- pH check performed in Treatability Lab using field pH instrument
- Lab Data -- pH value received from Inorganic Lab following full QA/QC procedures

LIME207C.XLC

3.2.3 Crystal Habit Modifier Study Data

The data from the testing of the crystal habit modifiers are presented in Table 3-17. None of the additives tested were successful in reducing the amount of crystals relative to the amount of total 207C material. The HR-25 additive exhibited reactions with the 207C material that evolved gas and created foaming upon addition. This additive was disqualified from further evaluation. The other additives tested did not exhibit any measurable effect in the amount of crystalline material present in the Pond 207C material. A possible explanation for the lack of success of the additive is that the Pond 207C material is a complex mixture of many anions and cations, any one of which may be inhibiting the additive's effectiveness.

3.2.4 Process Formulation Development Data

The development of the process formulation for testing 207C material included three stages of treatability testing; the development of a friable mix (pre-WAC) and the waste acceptance criteria (WAC) compliance testing Phase I and Phase II.

3.2.4.1 Pre-WAC Friable Mix Development

One of the desired properties of the treated waste is that the material be the consistency of a friable soil while still providing all the benefits of a chemical stabilization/solidification. Initially in the treatability study, a series of mixes with a wide range of additives, singly and in combination, were prepared for the sole purpose of determining if a friable material could be prepared. A summary of the mixes and the results of these mixes is provided in Table 3-18.

The results indicated that a friable product could be achieved using a variety of additives. However, relatively low water-to-pozzolan (W/P) ratios (approximately 0.1 to 0.3) were required. This indicates that extra pozzolan is needed to react with the free water in the short mixing time.

Although many of the mixes tested achieved a friable product, the potential candidates for WAC compliance testing had to be narrowed to no more than three. The behavior of the final product was used to select the most desirable mixes. Mixes that had excessive temperature increases, that tended to fuse into a monolith after 1-2 days curing (assumed to be representative of the curing/staging time for a full-scale system), or that tended to disaggregate or produce excessive fines were deemed to be less desirable and were eliminated. For these reasons, mixes of just lime (temperature increase, material turned to dust), just cement (tended to form monolith), and just fly ash (tended to form monolith) were dropped from further consideration.

TABLE 3-17

CRYSTAL HABIT MODIFIER TEST RESULTS
POND 207C MATERIAL
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Additive	Dosage (% By Weight)	Volume W/O Additive (mL Liquid/ mL Solids[1])	Volume with Additive (mL Liquid/ mL Solids[1])	Visual Observations
HR-4	2	36/54	40/523	No Change.
	15	31/49	INT	Gas evolved, additive hardened.
HR-12	2	40/52	40/52	No change.
	7.4	30/50	INT	Color of additive obscured measurement.
HR-15	2	37/54	37/56	No change.
	7.4	29/51	35/45	No change.
HR-25	1.5	38/54	38/53	Gas evolved, foaming.
LP-55	15	28/52	INT	Foaming, violent reaction.
CFR-1	2	31/54	37/53	Some gas evolved.
	10	38/58	48/55	Gas evolved.
8003	2	37/53	41/52	No change.
	15	32/48	36/44	No change.

INT Interference prevented volume reading.

TABLE 3-18

SUMMARY OF PRE-WAC MIXES
207C SLUDGE @ 1.7 SPECIFIC GRAVITY
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase: Not Compacted	Bulk Volumetric Increase: Compacted	Temperature Increase	Observations
1A	207°C @ 1.7 SG 358 g CaO 400 g	1 1.12	0.27	2.8 x	2.1 x	56.6°F → 96.0°F	Small hard pellets. After 4 hours began to expand; after 1 day broke 8-oz. jar container and became a fine powder and small pellets which easily crushed to powder.
2A	207°C @ 1.7 SG 358 g CaO 350 g	1 0.98	0.31	3.3 x	2.2 x	58.4°F → 63.4°F	Small hard pellets, uniform in size and color. Poured easily from glass jar.
3A	207°C @ 1.7 SG 358 g Fly ash 1,000 g	1 2.8	0.11	5 x	3.3 x	58.3°F → 64.2°F	Friable soil, clumps. Cured to hard uniform pellets or balls.
4A	207°C @ 1.7 SG 358 g Cement 850 g	1 2.37	0.13	4.5 x	3 x	59.1°F → 54.0°F	Hard uniform round pellets.
5A	207°C @ 1.7 SG 358 g CaO 150 g Fly ash 550 g	1 0.42 1.54	0.15	4 x	2.8 x	61.0°F → 64.0°F	Uniform pellets. After 2 days in jar, the material had expanded and some lime (white spots) formed.
6A	207°C @ 1.7 SG 358 g CaO 150 g Cement 450 g	1 0.42 1.25	0.18	3.7 x	2.3 x	61.0°F → 63.9°F	Hard small uniform pellets. Lime noticed to come out and there was a slight expansion of the material.
7A	207°C @ 1.7 SG 358 g $Ca(OH)_2$ 100 g Fly ash 650 g	1 0.28 1.81	0.14	4.5 x	3.2 x	60.0°F → 62.8°F	Small hard uniform pellets. Able to break out of jar with finger pressure.

TABLE 3-18 (Continued)
SUMMARY OF PRE-WAC MIXES
207C SLUDGE @ 1.7 SPECIFIC GRAVITY
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		Temperature Increase	Observations
					Not Compacted	Compacted		
8A	207°C @ 1.7 SG $Ca(OH)_2$ Cement	358 g 100 g 600 g	1 0.28 1.67	0.15	4.2 x	2.8 x	60.0°F → 62.5°F	Small uniform pellets. Pellet stuck together in glass jar which required strong finger pressure to break up.
9A	207°C @ 1.7 SG CaO Fly ash Cement	358 g 35.8 g 450 g 225 g	1 0.1 1.25 0.63	0.16	3.6 x	2.4 x	59.7°F → 63.6°F	Medium-size hard uniform pellets.
10A	207°C @ 1.7 SG $Ca(OH)_2$ Fly ash Cement	358 g 35.8 g 500 g 250 g	1 0.1 1.40 0.70	0.14	4.4 x	3 x	59.8°F → 62.7°F	Hard uniform medium-size pellets. Medium finger pressure needed to remove from glass jar.
11A	207°C @ 1.7 SG CaO CalSeal	358 g 35.8 g 600 g	1 0.1 1.67	0.17	4.3 x	2.8 x	59.2°F → 63.0°F	Small to very small, almost powder particles with some good-sized pellets. Poured easily from glass jar.
12A	207°C @ 1.7 SG CaO Silica Flour	358 g 35.8 g 550 g	1 0.1 1.54	0.19	4.2 x	2.4 x	59.1°F → 64.4°F	Small pellets, easily separated with finger to pour out of jar. Able to crush pellets with finger pressure to form paste.
13A	207°C @ 1.7 SG CaO Fly ash Cement	358 g 150 g 350 g 175 g	1 0.42 0.98 0.49	0.16	3.8 x	2.7 x	59.0°F → 64.8°F	Round, hard pellets. Some powder. Cured to very small to almost powder particles. Did not stick together.

TABLE 3-18 (Continued)
SUMMARY OF PRE-WAC MIXES
207C SLUDGE @ 1.7 SPECIFIC GRAVITY
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		Temperature Increase	Observations
					Not Compacted	Compacted		
14A	207°C @ 1.7 SG $Ca(OH)_2$ Fly ash Cement	358 g 100 g 400 g 200 g	1 0.28 1.12 0.56	0.16	4 x	2.9 x	58.8°F → 63.2°F	Medium-sized, uniform round pellets able to pour out of glass jar with only slight finger pressure.
15A	207°C @ 1.7 SG $Ca(OH)_2$ CalSeal	358 g 35.8 g 700 g	1 0.1 1.95	0.15	4.3 x	2.9 x	59.3°F → 62.8°F	Small pellets, dry and hard. Very hard pellets when cured.
16A	207°C @ 1.7 SG $Ca(OH)_2$ Silica flour	358 g 35.8 g 750 g	1 0.1 2.09	0.14	4.5 x	3 x	59.0°F → 63.2°F	Pellets, small and uniform. Able to crush with finger pressure.
17A	207°C @ 1.7 SG $Ca(OH)_2$ Fly ash Silica flour	358 g 18 g 690 g 123 g	1 0.05 1.93 0.34	0.13	4.8 x	3.4 x	62.6°F → 64.8°F	Uniform hard round pellets. Pea-size and smaller.

All mixes performed in a Hobart mixer on low speed setting.

* Lime mixed into sludge and allowed to react before the addition of other additive(s).

3.2.4.2 WAC Compliance Testing

Phase I. Based on the results of the pre-WAC testing, three additive formulas were selected. These mixes were:

- Hydrated lime and fly ash
- Hydrated lime, fly ash, and silica flour
- Hydrated lime, fly ash, and cement

Additional testing was then performed to determine WAC compliance over the anticipated operating ranges for water-to-pozzolan (W/P) ratios and waste loadings. Mixes performed with lime and fly ash were dosed with hydrated lime [$Ca(OH_2)$] at 5 percent by weight of waste. The 207C waste was tested at three specific gravities, 1.50, 1.75, and 1.98, respectively. The W/P ratios tested were 0.10, 0.20, and 0.30. A summary of the mixes using lime and fly ash is provided in Table 3-19. The mixes using lime, fly ash, and silica flour are summarized in Table 3-20. The mixes using lime, fly ash, and cement are summarized in Table 3-21.

The samples were submitted for TCLP, paint filter liquids test, and bulk density analysis. The analytical results of the mixes prepared with lime and fly ash are summarized in Table 3-22. The analytical results of the mixes prepared with lime, fly ash, and silica flour are summarized in Table 3-23. The analytical results of the mixes prepared with lime, fly ash, and cement are summarized in Table 3-24. The TCLP leachate data were plotted against the pH of the leachate and are provided in Appendix G.

The data shown on Tables 3-22 through 3-24 indicate that some of the analytes are leachable under certain conditions. None of the leachate concentrations exceeded the concentrations for the design WAC. However, all of the leachate concentrations for the uranium isotopes exceeded the 1 inch per year WAC concentrations. In some cases beryllium and cadmium leached at concentrations which exceeded the WAC concentrations. To a lesser extent, nitrate leached at concentrations exceeding the WAC concentration, although this phenomenon is not related to pH.

The graphs of TCLP extract pH versus leachate concentration, in Appendix G, are useful for determining the relationship between pH and leachate concentration. The isotopic uranium data shows that as the TCLP extract pH drops below 8.5, the concentration in the leachate increases. Beryllium leaches at detectable concentrations as the TCLP extract pH decreases below 6.5. Cadmium concentrations in the leachate increase as the TCLP extract pH of the leachate decreases to below 8.0.

TABLE 3-19

SUMMARY OF WAC PHASE I MIXES
207C SLUDGE (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS[1]	Observations
					Not Compacted	Compacted		
1A	207C @ 1.5 S.G. @ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C	297g 15g 1298g	1 0.05 4.37	0.10	9 X	5.5 X	0 psi	After 1 minute mixing formed a heavy pack on sides of bowl with powder in the center of bowl. Final product a moist powder. DRY MIX.
2A	207C @ 1.5 S.G. @ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C	445g 22g 972g	1 0.05 2.18	0.20	N/A	2.3 X	34 psi	Immediately turned to a cake icing consistency. After 1 minute mixing, turned to wet cake icing. Final product a pudding consistency. WET MIX.
3A	207C @ 1.5 S.G. @ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C	445g 22g 648g	1 0.05 1.45	0.30	N/A	1.8 X	20 psi	Immediately turned to consistency of cookie dough. After 30 seconds, turned to a wet cake icing. Final mix consistency of a milkshake, semi-pourable. WET MIX.
4A	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C	462g 23g 1349g	1 0.05 2.92	0.10	7.7 X	4.3 X	19 psi	Final product produced was a moist powder. DRY MIX.
5A	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C	462g 23g 675g	1 0.05 1.46	0.20	N/A	2.4 X	178 psi	Formed a friable soil (worm dirt) large clumps. After 1.5 minutes of mixing, was one large clay clump. Final product a dense molding clay. GOOD MIX, SLIGHTLY WET.
6A	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C	462g 23g 450g	1 0.05 0.97	0.30	N/A	1.7 X	83 psi	Immediately formed cookie dough which turned to a thin cake icing after 30 seconds. After 1 minute, turned to a semi-pourable consistency. Final product a thick milkshake consistency. WET MIX.

TABLE 3-19 (Continued)
SUMMARY OF WAC PHASE I MIXES
207C SLUDGE (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS(1)	Observations
					Not Compacted	Compacted		
7A	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C	400g 20g 700g	1 0.05 1.75	0.10	6.5 X	3.9 X	0 psi	Final product was a moist powder. DRY MIX.
8A	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C	500g 25g 437g	1 0.05 0.87	0.20	4.7 X	3.5 X	20 psi	After 35 seconds produced round pellets. Pellets broke down to produce a final product with consistency of moist powder. DRY MIX.
9A	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C	700g 35g 408g	1 0.05 0.58	0.30	5.4 X	2.7 X	113 psi	Immediately formed chunks and powder. After 30 seconds was a friable soil (worm dirt) small chunks or curds. After 1.5 minutes formed a bread dough. Final product was a molding clay, but easily broken, friable. GOOD MIX.

N/A Not available due to wet nature of product.
(1) It should be noted that crystals were observed in the broken cylinders which may account for the low UCS results.

TABLE 3-20

SUMMARY OF WAC PHASE I MIXES
207C SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS[1]	Observations
					Not Compacted	Compacted		
1C	207C @ 1.5 S.G. @ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	445g 22g 1102g 194g	1 0.05 2.48 0.43	0.15	6.4 X	3.6 X	57 psi	Final product was a moist powder. DRY MIX.
2C	207C @ 1.5 S.G. @ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	594g 30g 1103g 194g	1 0.05 1.86 0.33	0.20	N/A	2.4 X	43 psi	Immediately formed clay chunks which turned to bread dough after 30 seconds. Turned to cookie dough after 1 minute. Final product consistency of creamy peanut butter. WET MIX.
3C	207C @ 1.5 S.G. @ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	891g 44g 1324g 233g	1 0.05 1.48 0.21	0.25	N/A	2.1 X	26 psi	Immediately formed consistency of cookie dough. After 30 seconds, formed a wet icing which turned to a very thick milkshake after 1 minute, 30 seconds. Final product consistency of a milkshake, semi-pourable. WET MIX.
4C	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	346g 17g 572g 101g	1 0.05 1.65 0.29	0.15	4.8 X	3.3 X	0 psi	Immediately formed pea-sized pellets which broke down to powder. Final product was a moist powder. DRY MIX.
5C	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	462g 23g 573g 101g	1 0.05 1.24 0.22	0.20	N/A	2.3 X	148 psi	After 30 seconds, was consistency of a medium clump-sized friable soil (worm dirt). After 1 minute, formed bread dough, then dense clay. Final product was a soft molding clay. GOOD MIX.

TABLE 3-20 (Continued)
SUMMARY OF WAC PHASE I MIXES
207C SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS(1)	Observations
					Not Compacted	Compacted		
6C	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	577g 29g 573g 101g	1 0.05 0.99 0.17	0.25	N/A	1.8 X	106 psi	Immediately formed clay clumps which turned to cookie dough. After 1 minute of mixing, was a sticky cookie dough. Final product was a thick gritty fudge or cookie dough. WET MIX.
7C	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400g 20g 396g 70g	1 0.05 0.99 0.17	0.15	4.9 X	2.8 X	0 psi	After 30 seconds, formed pellets which began to break down to powder after 1 minute. Final product a moist powder. DRY MIX.
8C	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400g 20g 446g 79g	1 0.05 1.11 0.20	0.20	2.8 X	2.3 X	0 psi	Formed pea-sized round pellets after 1 minute of mixing. Final product was a moist powder. DRY MIX.
9C	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	800g 40g 476g 84g	1 0.05 0.59 0.10	0.25	2.8 X	2.1 X	19 psi	After 30 seconds, formed pellets which began to break down to powder after 1 minute. Final product a moist powder. DRY MIX.

N/A Not available due to wet nature of product.
(1) It should be noted that crystals were observed in the broken cylinders which may account for the low UCS results.

TABLE 3-21

SUMMARY OF WAC PHASE I MIXES
207C SLUDGE (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS[1]	Observations
					Not Compacted	Compacted		
1B	207C @ 1.5 S.G. @ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	297g 15g 577g 288g	1 0.05 1.94 0.97	0.15	5.5 X	2.7 X	84 psi	After 1 minute of mixing, was a powder mix with a lot of material packed on sides of bowl. Final product a moist powder. DRY MIX.
2B	207C @ 1.5 S.G.@ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	445g 22g 648g 324g	1 0.05 1.45 0.73	0.20	N/A	2.3 X	0 psi	Immediately formed clay clumps which turned to bread dough after 30 seconds. After 1 minute, became cookie dough, then cake icing. Final product a thick pudding or moist molding clay. WET MIX.
3B	207C @ 1.5 S.G. @ 56.3% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	594g 30g 692g 346g	1 0.05 1.16 0.58	0.25	N/A	2.1 X	38 psi	Immediately formed bread dough, then turned to consistency of cookie dough, then cake icing after 30 seconds. After 1 minute was consistency of wet cake icing, then a thickened milkshake after 2 minutes. Final product was a semi-pourable material. WET MIX.
4B	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	462g 23g 600g 300g	1 0.05 1.30 0.65	0.15	N/A	4.7 X	0 psi	Immediately formed pea-sized clumps or balls. After 30 seconds, formed pellets which broke down to a powder. Final product a moist powder. DRY MIX.
5B	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	462g 23g 450g 225g	1 0.05 0.97 0.49	0.20	N/A	2.5 X	127 psi	After 30 seconds, formed a friable soil (worm dirt), large clumps. After 1 minute, medium-sized clump friable soil. Final product a moist molding clay. GOOD MIX.

TABLE 3-21 (Continued)
SUMMARY OF WAC PHASE I MIXES
207C SLUDGE (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS[1]	Observations
					Not Compacted	Compacted		
6B	207C @ 1.75 S.G. @ 70.8% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	693g 35g 540g 270g	1 0.05 0.78 0.39	0.25	N/A	1.9 X	104 psi	After 10 seconds, consistency of bread dough which turned to cookie dough after 30 seconds. After 1 minute, became cake icing. Final product the consistency of chunky cake icing or peanut butter. WET MIX.
7B	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400g 20g 311g 155g	1 0.05 0.78 0.39	0.15	4.7 X	2.6 X	0 psi	Final product consistency of a moist powder. DRY MIX.
8B	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	500g 25g 292g 146g	1 0.05 0.58 0.29	0.20	3.2 X	2 X	0 psi	Final product consistency of a moist powder. DRY MIX.
9B	207C @ 1.98 S.G. @ 82.5% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	700g 35g 327g 163g	1 0.05 0.47 0.23	0.25	3.1 X	2.3 X	0 psi	After 30 seconds of mixing, formed pellets which broke down to powder after 1 minute. Formed a heavy packing on sides of bowl. Final product a moist powder. DRY MIX.

N/A Not available due to wet nature of product.
(1) It should be noted that crystals were observed in the broken cylinders which may account for the low UCS results.

TABLE 3-22

WAC PHASE I ANALYTICAL RESULTS
207C MIXES (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		#1A-207C	#2A-207C	#3A-207C	#4A-207C	#5A-207C	#6A-207C	#7A-207C	#8A-207C	#9A-207C	#8Dup-207C(1)
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0301173 P0301174	P0301175	P0301176 P0301177	P0301178 P0301179	P0301180	P0301181 P0301182	P0301183 P0301184	P0301185	P0301186 P0301187	P0301420
	Date:			02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/17/95
	W/P:			0.10	0.20	0.30	0.10	0.20	0.30	0.10	0.20	0.30	0.15
	% Solids:			56.3%	56.3%	56.3%	70.8%	70.8%	70.8%	82.5%	82.5%	82.5%	82.5%
Analyte	Units												
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-134	pCi/L	3,510,000	12,800	< 5	NS	< 6	< 4	NS	< 7	< 7	NS	< 5	NT
Cs-137	pCi/L	111,000	737	< 6	NS	< 7	< 5	NS	< 7	< 7	NS	< 6	NT
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Ra-226	pCi/L	117,000	415	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
U-233/234	pCi/L	35,200	254	120 ± 20	NS	470 ± 50	370 ± 40	NS	510 ± 70	440 ± 50	NS	890 ± 90	720 ± 90
U-235	pCi/L	1,410	10.2	5.1 ± 0.8	NS	17 ± 6	15 ± 2	NS	21 ± 4	18 ± 3	NS	42 ± 10	28 ± 6
U-238	pCi/L	24,500	177	180 ± 20	NS	730 ± 80	580 ± 60	NS	780 ± 100	670 ± 80	NS	1400 ± 200	1100 ± 200
Arsenic	mg/L	13.6	0.142	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Beryllium	mg/L	1.43	0.0142	<0.0005	NS	<0.0005	<0.0005	NS	<0.0005	<0.0005	NS	0.007	0.005
Cadmium	mg/L	5.19	0.0518	<0.005	NS	0.12	0.034	NS	0.18	0.092	NS	0.28	0.25
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Nitrate/Nitrite	mg/L	15,900	166	440	NS	1100	900	NS	1700	1400	NS	2600	1400
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2	2	NS	2	2
Final Leachate pH	Units	NA	NA	8.3	NS	6.6	6.9	NS	6.5	6.9	NS	6.0	6.1

TABLE 3-22 (Continued)
WAC PHASE I ANALYTICAL RESULTS
207C MIXES (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1A-207C	#2A-207C	#3A-207C	#4A-207C	#5A-207C	#6A-207C	#7A-207C	#8A-207C	#9A-207C	#8Dup-207C[1]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0301173 P0301174	P0301175	P0301176 P0301177	P0301178 P0301179	P0301180	P0301181 P0301182	P0301183 P0301184	P0301185	P0301186 P0301187	P0301420
Date:				02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/14/95	02/17/95
W/P:				0.10	0.20	0.30	0.10	0.20	0.30	0.10	0.20	0.30	0.15
% Solids:				56.3%	56.3%	56.3%	70.8%	70.8%	70.8%	82.5%	82.5%	82.5%	82.5%
Analyte	Units												
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0	NA
Bulk Density	g/cc	NA	NA	1.09	1.25	1.20	1.09	1.25	NSQ	1.12	NSQ	1.20	NA

(1) Field duplicate mix of 021495-7A-207C; P0301242
NT Not tested for this analyte.
NA Not applicable.
NS Not submitted for analysis.
NSQ Insufficient sample quantity available to obtain a measurement.
Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

TABLE 3-23

WAC PHASE I ANALYTICAL RESULTS
207C MIXES (ADDITIVES: LIME, FLY ASH AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1C-207C	#2C-207C	#3C-207C	#4C-207C	#5C-207C	#6C-207C	#7C-207C	#8C-207C	#9C-207C
Sample No.:		0.0068 in/yr infiltration	1 in/yr Infiltration	P0301299 P0301300	P0301301	P0301302 P0301303	P0301304 P0301305	P0301306	P0301307 P0301308	P0301309 P0301310	P0301311	P0301312 P0301313
Date:				02/16/95	02/16/95	02/16/95	02/16/95	02/16/95	02/16/95	02/16/95	02/16/95	02/16/95
W/P:				0.15	0.20	0.25	0.15	0.20	0.25	0.15	0.20	0.25
% Solids:				56.3%	56.3%	56.3%	70.8%	70.8%	70.8%	82.5%	82.5%	82.5%
Analyte	Units											
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT
Cs-134	pCi/L	3,510,000	12,800	NT	NS	NT	NT	NS	NT	NT	NS	NT
Cs-137	pCi/L	111,000	737	NT	NS	NT	NT	NS	NT	NT	NS	NT
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT
Ra-226	pCi/L	117,000	415	NT	NS	NT	NT	NS	NT	NT	NS	NT
U-233/234	pCi/L	35,200	254	240 ± 30	NS	420 ± 50	390 ± 40	NS	580 ± 70	630 ± 70	NS	1000 ± 100
U-235	pCi/L	1,410	10.2	13 ± 2	NS	18 ± 3	15 ± 3	NS	26 ± 5	27 ± 5	NS	52 ± 11
U-238	pCi/L	24,500	177	380 ± 40	NS	670 ± 70	610 ± 70	NS	940 ± 100	890 ± 110	NS	1600 ± 200
Arsenic	mg/L	13.6	0.142	NT	NS	NT	NT	NS	NT	NT	NS	NT
Beryllium	mg/L	1.43	0.0142	0.0016*	NS	0.0030	<0.0007*	NS	0.005	0.006	NS	0.018
Cadmium	mg/L	5.19	0.0518	0.11	NS	0.13	0.11	NS	0.23	0.23	NS	0.31
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT
Nitrate/Nitrite	mg/L	15,900	166	540	NS	980	1200	NS	1600	1800	NS	590
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2	2	NS	2
Final Leachate pH	Units	NA	NA	6.3	NS	6.0	6.6	NS	6.0	6.0	NS	5.6

TABLE 3-23 (Continued)
WAC PHASE I ANALYTICAL RESULTS
207C MIXES (ADDITIVES: LIME, FLY ASH AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1C-207C	#2C-207C	#3C-207C	#4C-207C	#5C-207C	#6C-207C	#7C-207C	#8C-207C	#9C-207C
Sample No.:		0.0068 in/yr infiltration	1 in/yr Infiltration	P0301299 P0301300	P0301301	P0301302 P0301303	P0301304 P0301305	P0301306	P0301307 P0301308	P0301309 P0301310	P0301311	P0301312 P0301313
Date:				02/16/95	02/16/95	02/16/95	02/16/95	02/16/95	02/16/95	02/16/95	02/16/95	02/16/95
W/P:				0.15	0.20	0.25	0.15	0.20	0.25	0.15	0.20	0.25
% Solids:				56.3%	56.3%	56.3%	70.8%	70.8%	70.8%	82.5%	82.5%	82.5%
Analyte	Units											
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0
Bulk Density	g/cc	NA	NA	1.21	1.24	1.22	1.28	1.26	1.22	1.17	1.29	1.28

NA Not applicable
NS Not submitted for analysis
NT Not tested for this analysis
* Result determined by a single-point method of standard additions
Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

TABLE 3-24

WAC PHASE I ANALYTICAL RESULTS
207C MIXES (ADDITIVES: LIME, FLY ASH AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1B-207C	#2B-207C	#3B-207C	#4B-207C	#5B-207C	#6B-207C	#7B-207C	#8B-207C	#9B-207C	#9Dup-207C[1]
Sample No.:				P0301231 P0301232	P0301233	P0301234 P0301235	P0301236 P0301237	P0301238	P0301239 P0301240	P0301241 P0101242	P0301243	P0301244 P0301245	P0301421
Date:		0.0068 in/yr Infiltration	1 in/yr Infiltration	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/17/95
W/P:				0.15	0.20	0.25	0.15	0.20	0.25	0.15	0.20	0.25	0.15
% Solids:				56.3%	56.3%	56.3%	70.8%	70.8%	70.8%	82.5%	82.5%	82.5%	82.5%
Analyte	Units												
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-134	pCi/L	3,510,000	12,800	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-137	pCi/L	111,000	737	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Ra-226	pCi/L	117,000	415	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
U-233/234	pCi/L	35,200	254	220 ± 30	NS	380 ± 50	360 ± 40	NS	720 ± 80	520 ± 70	NS	1000 ± 100	470 ± 50
U-235	pCi/L	1,410	10.2	11 ± 2	NS	18 ± 3	15 ± 3	NS	25 ± 7	26 ± 5	NS	51 ± 11	20 ± 4
U-238	pCi/L	24,500	177	350 ± 40	NS	600 ± 70	580 ± 70	NS	1100 ± 200	820 ± 110	NS	1600 ± 200	740 ± 80
Arsenic	mg/L	13.6	0.142	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Beryllium	mg/L	1.43	0.0142	<0.0009*	NS	<0.0007*	<0.0008*	NS	0.0025	<0.0009*	NS	0.011	<0.002**
Cadmium	mg/L	5.19	0.0518	0.021	NS	0.072	0.072	NS	0.14	0.038	NS	0.20	0.077
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Nitrate/Nitrite	mg/L	15,900	166	580	NS	3,800	1100	NS	1600	1600	NS	2200	1800
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NA	2	2	NA	2	2
Final Leachate pH	Units	NA	NA	7.9	NS	6.9	7.0	NA	6.6	7.5	NA	6.0	7.2

TABLE 3-24 (Continued)
WAC PHASE I ANALYTICAL RESULTS
207C MIXES (ADDITIVES: LIME, FLY ASH AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1B-207C	#2B-207C	#3B-207C	#4B-207C	#5B-207C	#6B-207C	#7B-207C	#8B-207C	#9B-207C	#9Dup-207C[1]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0301231 P0301232	P0301233	P0301234 P0301235	P0301236 P0301237	P0301238	P0301239 P0301240	P0301241 P0101242	P0301243	P0301244 P0301245	P0301421
Date:				02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/15/95	02/17/95
W/P:				0.15	0.20	0.25	0.15	0.20	0.25	0.15	0.20	0.25	0.15
% Solids:				56.3%	56.3%	56.3%	70.8%	70.8%	70.8%	82.5%	82.5%	82.5%	82.5%
Analyte	Units												
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0	NA
Bulk Density	g/cc	NA	NA	1.31	1.24	1.30	1.30	1.30	1.33	NSQ	1.08	1.20	NA

(1) Field duplicate mix of 021595-7B-207C; P0301242.
NA Not applicable
* Result determined by a single-point method of standard additions
** Elevated detection limit reported due to matrix interference
NSQ Insufficient sample quantity available to obtain a measurement
NS Not submitted for analysis
NT Not tested for this analysis

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

Phase II. A series of mixes was performed to evaluate the relationship between lime dosage, curing time, and leachate pH to try to increase the TCLP extract pH values shown in Phase I. Based on the Phase I data for all the sludges, it was evident that the leachability of the metals and radionuclides could be greatly reduced by controlling the pH of the TCLP extract. The test matrix evaluated three lime dosages and four curing times to determine the effect of these variables on the TCLP extract pH. The pH data are summarized on Table 3-25. The results show that the desired pH can be obtained, even with only a one day curing time. Beryllium and cadmium were selected as surrogate analytes for this test, and all sample results were below detection limits (see data in Appendix F).

Phase II WAC compliance tests were required to demonstrate compliance with the leachability criteria which was not consistently demonstrated during Phase I. For the Phase II WAC compliance tests, the lime, cement, and fly ash additive combination was selected as the preferred formulation. The lime, cement, and fly ash mixture consistently resulted in higher pH compared to the lime and fly ash mixture, which is more favorable for reducing leachate concentrations. Based on the Phase I results the silica flour and fly ash formulation offered no advantage compared to the lime, cement, and fly ash formulation. In addition, the lime, cement, and fly ash formulation has been demonstrated to be successful in previous treatability studies with the 207C material (HNUS 1992b).

Phase II involved a series of tests that were performed at the high and low W/P ratios identified from Phase I with different lime dosages to test compliance with leachability criteria. A summary of the mixes prepared using lime, fly ash, and cement is provided in Table 3-26. Table 3-27 provides a summary of the analytical results. Graphs plotting TCLP extract concentrations versus extract pH are provided in Appendix G.

The TCLP leachate results provided in Table 3-27 for the 207C waste are compared to the WACs. Two WACs are shown on Table 3-27, one is associated with the design infiltration rate of 0.0068 inches per year and the other is associated with a 1 inch per year infiltration rate. The development of the WACs are discussed in Appendix B.

All analytes leached at concentrations less than the design WAC concentrations with the exception of sodium. All analytes also leached at concentrations less than the 1 inch per year WAC concentrations with the exception of arsenic, nitrate/nitrite, and sodium.

The figures provided in Appendix G indicate that the increase in the lime dosage from 5 percent to 7.5 percent resulted in an increase in the TCLP leachate pH. The pH of the leachate for the Phase II mixes ranged from 11.5 to 12.0 as shown on Figure G-4A.

TABLE 3-25

SUMMARY OF LEACHATE pH FOR HYDRATED LIME DOSAGE TEST
207C WAC PHASE II TESTING
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Additives	Lime Addition	24-Hour Cure pH	48-hour Cure pH	72-Hour Cure pH	7-Day Cure pH
Lime and Fly Ash	5%	8.6	8.8	10.2	10.3
Lime and Fly Ash	10%	10.5	10.5	10.4	10.4
Lime and Fly Ash	15%	11.0	10.9	11.0	11.1
Lime, Fly Ash and Cement	5%	11.7	11.8	11.9	11.8
Lime, Fly Ash and Cement	10%	11.8	11.9	12.0	11.8
Lime, Fly Ash and Cement	15%	11.6	11.9	12.1	11.9

TABLE 3-26

SUMMARY OF WAC PHASE II MIXES
207C SLUDGE (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Observations
1	207C @ 56.3% Solids	297 g	1.0	0.15	N/A
	$Ca(OH)_2$	22.3 g	0.075		
	Fly Ash, Type C	577 g	1.94		
	Cement, Type I/II	288 g	0.97		
2	207C @ 56.3% Solids	594 g	1.0	0.35	30 sec - Wet pudding consistency 1 min - Slightly wetter, runny milkshake 2 min - Runny milkshake 2.5 min - Very wet, runny milkshake
	$Ca(OH)_2$	44.5 g	0.075		
	Fly Ash, Type C	494 g	0.83		
	Cement, Type I/II	247 g	0.42		
3	207C @ 82.5% Solids	400 g	1.0	0.15	N/A
	$Ca(OH)_2$	30 g	0.075		
	Fly Ash, Type C	311 g	0.78		
	Cement, Type I/II	156 g	0.39		
4	207C @ 82.5% Solids	700 g	1.0	0.35	30 sec - Dry, many small clumps, pebbles 1 min - Moist, friable dirt, good 2 min - Moist, clumping, wet sand 2.5 min - Moist, clumping wet sand
	$Ca(OH)_2$	35 g	0.05		
	Fly Ash, Type C	233 g	0.33		
	Cement, Type I/II	117 g	0.17		
5	207C @ 82.5% Solids	700 g	1.0	0.35	30 sec - Dry, many small clumps, pebbles 1 min - Moist, friable soil, good 2 min - Moist, packing soil 2.5 min - Moist, packing soil, friable soil
	$Ca(OH)_2$	52.5 g	0.075		
	Fly Ash, Type C	233 g	0.33		
	Cement, Type I/II	117 g	0.17		
6	207C @ 82.5% Solids	700 g	1.0	0.35	30 sec - Dry, many small clumps, pebbles 1 min - Dry, pebbles 2 min - Dry, powder-like 2.5 min - Dry, powder-like soil
	$Ca(OH)_2$	70 g	0.10		
	Fly Ash, Type C	233 g	0.33		
	Cement, Type I/II	117 g	0.17		

TABLE 3-27

WAC PHASE II ANALYTICAL RESULTS
207C MIXES (ADDITIVES: LIME, FLY ASH AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1 0.0068 in/yr Infiltration	WAC for Scenario 1 1 in/yr Infiltration	#1-207C	#2-207C	#3-207C	#4-207C	#5-207C	#6-207C
	Sample No.:			P0304213 P0304214	P0304215 P0304216	P0304217 P0304218	P0304219 P030220	P0304221 P0304222	P0304223 P0304224
	Date:			03/20/95	03/20/95	03/20/95	03/20/95	03/20/95	03/20/95
	W/P:			0.15[1]	0.35[1]	0.15[1]	0.35[1]	0.35[2]	0.35[3]
	% Solids:			56.3	56.3	82.5	82.5	82.5	82.5
Analyte	Units								
Am-241	pCi/L	17,100	74.5	< 0.3	< 0.2	< 0.07	2.8 ± 0.6	1.7 ± 0.4	1.2 ± 0.5
Cs-134	pCi/L	3,510,000	12,800	< 5	< 6	< 5	< 5	< 6	< 6
Cs-137	pCi/L	111,000	737	< 6	< 7	< 6	< 7	< 6	< 7
Pu-238	pCi/L	NA	NA	< 0.03	< 0.08	< 0.03	<0.08	<0.03	<0.03
Pu-239/240	pCi/L	1,070	4.43	< 0.03	< 0.08	< 0.03	< 0.03	< 0.03	< 0.08
Ra-226	pCi/L	117,000	415	0.4 ± 0.1	0.4 ± 0.1	0.2 ± 0.1	0.6 ± 0.1	1.0 ± 0.2	0.5 ± 0.1
U-233/234	pCi/L	35,200	254	0.062 ± 0.050	0.15 ± 0.09	0.25 ± 0.10	0.16 ± 0.08	0.18 ± 0.09	0.095 ± .062
U-235	pCi/L	1,410	10.2	0.041 ± 0.041	< 0.1	< 0.08	< 0.03	0.053 ± 0.047	< 0.08
U-238	pCi/L	24,500	177	< 0.1	0.16 ± 0.09	0.25 ± 0.10	0.18 ± 0.09	0.11 ± 0.09	0.14 ± 0.08
Beryllium	mg/L	1.43	0.0142	< 0.003*	< 0.004*	< 0.002**	< 0.002**	< 0.002**	< 0.005*
Cadmium	mg/L	5.19	0.0518	< 0.005	< 0.005	< 0.005	< 0.005	0.005	< 0.005
Arsenic	mg/L	13.6	0.142	0.8	0.4	0.5	0.6	0.5	0.5
Chromium	mg/L	142	0.881	0.18**	0.14	0.15	0.16	0.15	0.14

TABLE 3-27 (Continued)
WAC PHASE II ANALYTICAL RESULTS
207C MIXES (ADDITIVES: LIME, FLY ASH AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID: / Sample No.: / Date: / W/P: / % Solids:		WAC for Scenario 1 0.0068 in/yr Infiltration	WAC for Scenario 1 1 in/yr Infiltration	#1-207C P0304213 P0304214 03/20/95 $0.15^{(1)}$ 56.3	#2-207C P0304215 P0304216 03/20/95 $0.35^{(1)}$ 56.3	#3-207C P0304217 P0304218 03/20/95 $0.15^{(1)}$ 82.5	#4-207C P0304219 P030220 03/20/95 $0.35^{(1)}$ 82.5	#5-207C P0304221 P0304222 03/20/95 $0.35^{(2)}$ 82.5	#6-207C P0304223 P0304224 03/20/95 $0.35^{(3)}$ 82.5
Analyte	Units								
Nitrate/Nitrite	mg/L	15,900	166	570	1,200	1,900	870	2,700	700
Sodium	mg/L	1,750	14.9	1,100	1,900	3,000	4,200	4,300	3,900
Nickel	mg/L	NA	NA	0.05**	< 0.02	< 0.02	0.02	0.03	0.02
Lead	mg/L	NA	NA	0.05**	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
TCLP Extraction Fluid	NA	NA	NA	2	2	2	2	2	2
Final Leachate pH	Units	NA	NA	11.9	11.9	12.0	11.5	11.8	11.9
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0

(1) 7.5% linear addition by weight of waste
(2) 5% linear address by weight of waste
(3) 10% linear address by weight of waste
* Result determined by a single-point method of standard additions
** Presence of a possible matrix interference.

NA Not applicable
NS Not submitted for analysis
NT Not tested for this analyte

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

All of the analytes, with the exception of arsenic, nitrate/nitrite, and sodium, show a decrease in leachability as the pH of the TCLP leachate increases. Arsenic leaches at a fairly constant concentration at the pH values shown on Figure G-4J. This is a result of arsenic having amphoteric properties (i.e., soluble at low and high pHs). Arsenic is least soluble when the pH is in the neutral range. It should be noted that at the higher pH ranges shown on Figure G-4J, the arsenic leachate concentration is less than the WAC for the design infiltration rate. Nitrate/nitrite and sodium leachate concentrations show no dependency on pH.

As shown on Table 3-27, the TCLP extract for Phase II lime, cement, and fly ash mixes were analyzed for lead and nickel, which are LDR constituents associated with the hazardous waste codes for 207C sludge. All LDR metals, including cadmium and chromium, leached at levels below their respective LDR standards.

3.3 CLARIFIER SLUDGE RESULTS

Testing performed on Clarifier sludge included an initial characterization, a lime addition study, friable mix development (pre-WAC), waste acceptance criteria compliance (WAC - Phase I), and final evaluation (WAC - Phase II).

3.3.1 Initial Characterization Data

The as received Clarifier material was submitted for baseline analysis and TCLP and COC analysis. A summary of the results are provided in Table 3-28.

Sample analysis was conducted for selected contaminants determined to be of potential concern when the treated sludge is eventually placed in the OU4 closure. The data show that there are relatively high levels of the analytes in the clarifier sludge compared to the Pond 207C waste and the 207A/B sludge.

A sample of the Clarifier sludge was tested using TCLP to determine the leachability of the as received material. The results indicate that plutonium 239/240, beryllium and cadmium leached at concentrations above the WAC associated with a 1 inch per year infiltration rate, which is considered to be a future worst-case scenario. Cadmium leached above the WAC associated with the design infiltration rate, indicating that untreated clarifier material could not be placed in the OU4 closure.

3.3.2 Lime Addition Study Data

An abbreviated lime study was performed on the Clarifier material because of limited waste material availability. Additions of hydrated lime [$Ca(OH_2)$] and quicklime (CaO) were tested at two points. Dosages

TABLE 3-28

SUMMARY OF BASELINE ANALYTICAL RESULTS
CLARIFIER "AS RECEIVED" MATERIAL
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		Clarifier, "As Received"	Clarifier, TCLP(1)
Sample No.: Date: W/P: % Solids:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0297299 01/03/95 NA 38.1	P0297300 01/03/95 NA NA
Analyte	Units(2)				
Am-241	pCi/L	17,100	74.5	13,000 ± 2,000 pCi/g	34 ± 4
Cs-134	pCi/L	3,510,000	12,800	< 4 pCi/g	<3
Cs-137	pCi/L	111,000	737	< 6 pCi/g	< 4
Pu-238	pCi/L	NA	NA	89 ± 37 pCi/g	< 7
Pu-239/240	pCi/L	1,070	4.43	3,900 ± 400 pCi/g	19 ± 6
Ra-226	pCi/L	117,000	415	6.2 ± 0.7 pCi/g	< 0.3
U-233/234	pCi/L	35,200	254	28 ± 3 pCi/g	1.4 ± 0.9
U-235	pCi/L	1,410	10.2	1.1 ± 0.2 pCi/g	< 1
U-238	pCi/L	24,500	177	32 ± 4 pCi/g	2.1 ± 1.1
Strontium 89	pCi/L	NA	NA	0.53 ± 0.06 pCi/g	< 3
Strontium 90	pCi/L	NA	NA	0.88 ± 0.27 pCi/g	< 3
Beryllium	mg/L	1.43	0.0142	320 mg/kg	1.0
Cadmium	mg/L	5.19	0.0518	2,100 mg/kg	15
pH	Units	NA	NA	9.8	4.8 (leachate)
Bulk Density	g/cc	NA	NA	1.45	NT

NA Not applicable
NT Not tested
(1) TCLP extraction fluid 2
(2) Units unless otherwise noted

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

of approximately 4 percent and 16 percent, of the total sludge weight, were evaluated for both hydrated lime and quicklime. The testing was conducted on clarifier sludge at 38.1 percent solids. The results of the lime study are depicted in Figure 3-3.

Figure 3-3 shows that the use of hydrated lime resulted in higher pH values than the quicklime. The hydrated lime curve began to flatten at a pH value of 12.5. No data was collected for bacterial plate counts.

3.3.3 Process Formulation Development Data

The development of the process formulation for testing Clarifier sludge included three stages of testing; the development of a friable mix (Pre-WAC) and the WAC compliance testing Phase I and Phase II.

3.3.3.1 Pre-WAC Friable Mix Development

One of the desired properties of the treated sludge is that the material be the consistency of a friable soil. In an attempt to achieve this consistency while still obtaining all the benefits of a chemical stabilization and solidification (CSS) matrix, the additives which were demonstrated to be most effective in the 207A/B and 207C pre-WAC mixes were evaluated. A summary of the mixes and the results of these mixes are presented in Table 3-29.

The results indicated that a friable product could be achieved using a variety of additives. However, relatively low water-to-pozzolan (W/P) ratios (approximately 0.15 to 0.2) were required. This indicates that extra pozzolan is needed to react with the free water in the short mixing time.

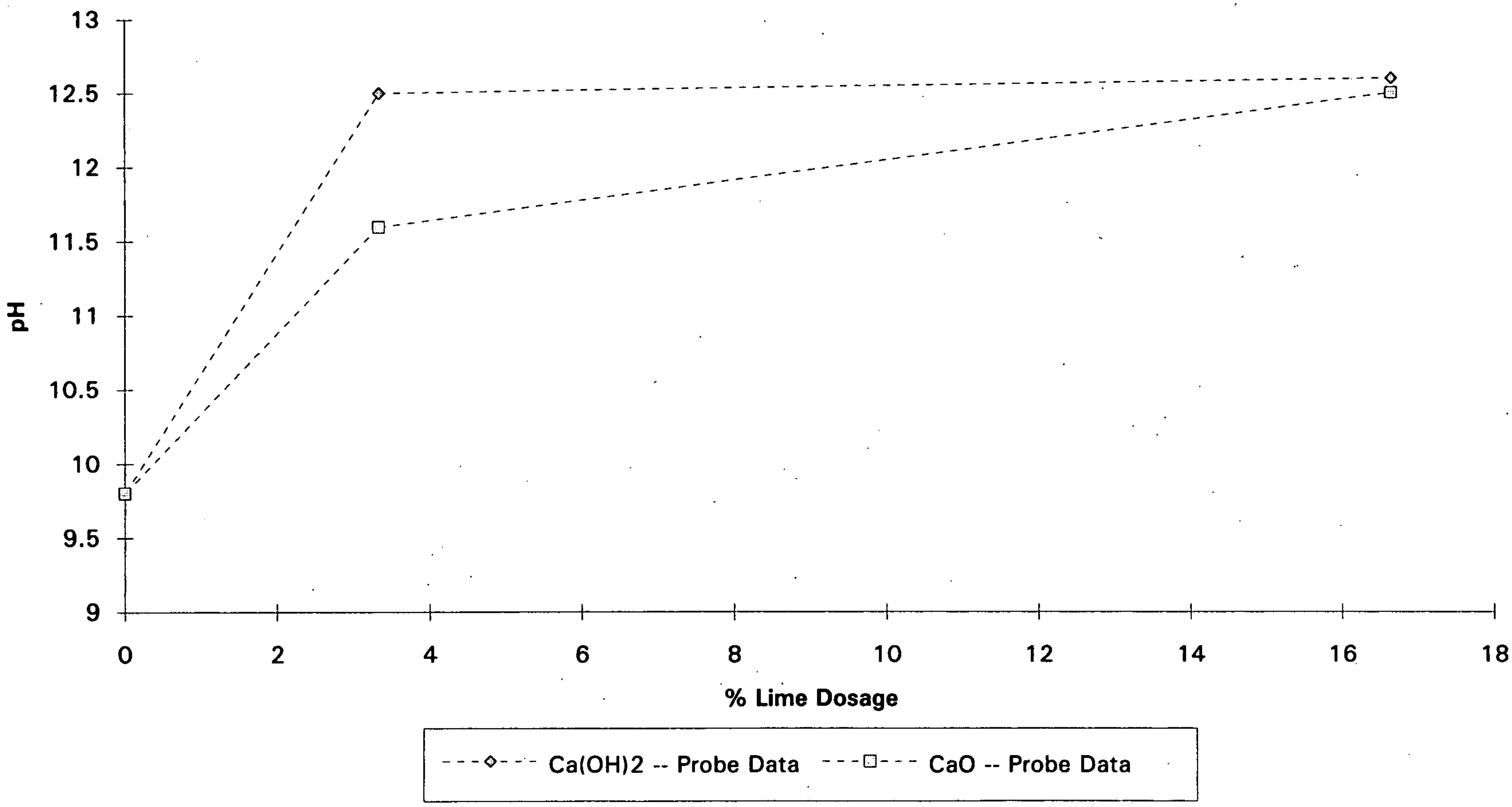
Only four formulations were evaluated to determine if a friable product could be produced, as shown in Table 3-29. Lime as a single additive was eliminated from further consideration based on the difficulties and length of mixing time require to form a friable product.

3.3.3.2 WAC Compliance Testing

Phase I. Based on the results of the pre-WAC testing, three additives were selected for further evaluation:

- Hydrated lime and fly ash
- Hydrated lime, fly ash, and silica flour
- Hydrated lime, fly ash, and cement

Figure 3-3
Rocky Flats Treatability Study
Lime Addition Study for Clarifier
Rocky Flats, Colorado



• Probe Data -- pH check performed in Treatability Lab using field pH instrument

LIMECLAR.XLC

TABLE 3-29

**SUMMARY OF PRE-WAC MIXES
CLARIFIER SLUDGE
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO**

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase		Temperature Increase	Observations
				Not Compacted	Compacted		
1	Clarifier 250 g $Ca(OH)_2$ 325 g	1 1.3	0.48	3.3 X	N/A	61.8°F → 61.4°F	Small round uniform pellets. Note that it took 53 minutes to make all the additions while mixing to achieve a friable or pellet consistency.
2	Clarifier 250 g $Ca(OH)_2$ 12.5 g Fly Ash 850 g	1 0.05 3.4	0.18	5.1 X	N/A	61.0°F → 61.5°F	Round, small hard pellets.
3	Clarifier 250 g $Ca(OH)_2$ 12.5 g Fly Ash 8.4.2 g Silica Flour 144 g	1 0.05 3.27 0.58	0.16	5.1 X	N/A	60.0°F → 61.2°F	Pellets, small round, clean.
4	Clarifier 250 g $Ca(OH)_2$ 12.5 g Cement 700 g Fly Ash 600 g	1 0.05 1.2 2.4	0.17	4.7 X	N/A	61.6°F → 61.0°F	Pellets, round, small and hard.

All mixes performed in a Hobart mixer.
Clarifier "as received" is 38.1% solids.

* Lime mixed into sludge and allowed to react before the addition of other additive(s).

N/A = Not Analyzed. Pellets formed, didn't attempt to compact by tamping on table.

Additional testing was then performed to determine WAC compliance over the anticipated operating ranges for waste loading, percent solids of the clarifier and the water-to-pozzolan (W/P) ratio. A summary of the mixes performed with lime and fly ash is provided in Table 3-30. A summary of the mixes performed using lime, fly ash, and silica flour is provided in Table 3-31. A summary of the mixes performed using lime, fly ash, and cement is provided in Table 3-32.

The samples were submitted for TCLP, paint filter liquids test, and bulk density. The analytical results of the mixes performed with lime and fly ash are provided in Table 3-33. A summary of the analytical results of the mixes performed with lime, fly ash, and silica flour are provided in Table 3-34. The analytical results of the lime, fly ash, and cement are summarized in Table 3-35. The TCLP leachate data were plotted against pH and are provided in Appendix G.

The data shown on Tables 3-33 through 3-35 indicate that some of the analytes are leachable under certain conditions. Cadmium and beryllium leachate concentrations exceeded the concentrations for the design WAC in some cases. In addition, all of the leachate concentrations for the uranium isotopes exceeded the 1 inch per year WAC concentrations. In some cases beryllium and cadmium leached at concentrations which exceeded the WAC concentrations. To a lesser extent, nitrate/nitrite leached at concentrations exceeding the WAC concentration, although this phenomenon is not related to pH.

The graphs of TCLP extract pH versus leachate concentration, in Appendix G, are useful for determining the relationship between pH and leachate concentration. The isotopic uranium data shows that as the TCLP extract pH drops below 8.5, the concentration in the leachate increases. Beryllium leaches at detectable concentrations as the TCLP extract pH decreases below 6.0. Cadmium concentrations in the leachate increase as the TCLP extract pH decreases to below 8.0.

Phase II. Phase II WAC compliance tests were required to demonstrate compliance with the leachability criteria which was not consistently demonstrated during Phase I. For the Phase II WAC compliance tests, the lime, cement, and fly ash additive combination was selected as the preferred formulation. The lime, fly ash, and cement mixture consistently resulted in higher pH compared to the lime and fly ash mixture. A mixture with a higher pH is more favorable for reducing leachate concentrations. Based on the Phase I results the fly ash and silica flour formulation offered no advantage compared to the lime, cement, and fly ash formulation. In addition, the lime, fly ash, and cement formulation has been demonstrated to be successful in previous treatability studies with the 207C material (HNUS 1992b).

TABLE 3-30

SUMMARY OF WAC PHASE I MIXES
CLARIFIER SLUDGE (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1A	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash Type C	400 g 20 g 1333 g	1 0.05 3.33	0.24	N/A	2.4 X	> 637 psi	Immediately formed large clay clumps, then turned to a smooth cake icing. Final consistency after 2.5 minutes of mixing was a moist, smooth spreadable cake icing. WET MIX.
2A	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C	400 g 20 g 1143 g	1 0.05 2.86	0.28	N/A	2.3 X	> 637 psi	Immediately formed clay clumps, which then turned to a smooth cake icing. The final product after 2.5 minutes of mixing was a stiff, moist clay or smooth thick sticky cake icing. WET MIX.
3A	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C	400 g 20 g 941 g	1 0.05 2.35	0.34	N/A	2 X	> 637 psi	Immediately formed large clay clumps and sticking to sides of bowl. Final product after mixing was a moist to wet molding clay. WET MIX.
4A	Clarifier @30% Solids $Ca(OH)_2$ Fly Ash, Type C	400 g 20 g 1167 g	1 0.05 2.92	0.24	N/A	2.9 X	> 637 psi	After 1 minute of mixing formed large clay clumps. Material packed on sides of bowl. Final product after 2.5 minutes of mixing was a stiff molding clay, dry and hard. WET MIX.
5A	Clarifier @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C	400 g 20 g 1000 g	1 0.05 2.50	0.28	N/A	2.6 X	557 psi	After 30 seconds of mixing formed a cake icing and the final product after 2.5 minutes of mixing was a very smooth cake icing. WET MIX.
6A	Clarifier @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C	400 g 20 g 824 g	1 0.05 2.06	0.34	N/A	2.3 X	508 psi	Immediately packed to sides of bowl in a cake icing consistency. The final product was a very smooth cake icing. WET MIX.

TABLE 3-30 (Continued)
SUMMARY OF WAC PHASE I MIXES
CLARIFIER SLUDGE (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
7A	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly ash, Type C	400 g 20 g 1033 g	1 0.05 2.58	0.24	4.9 X	3 X	289 psi	This mix began to pack to sides of bowl after 30 seconds. Mostly moist powder. Final product was a moist powder or dirt consistency. DRY MIX.
8A	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly ash, Type C	400 g 20 g 886 g	1 0.05 2.21	0.28	N/A	2.7 X	497 psi	After 1 minute of mixing the moist powder began packing on sides of bowl and after 2 minutes clay clumps began forming and pulling material off the sides of the bowl. Final product was a bread dough consistency. GOOD MIX.
9A	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly ash, Type C	400 g 20 g 729 g	1 0.05 1.82	0.34	N/A	2.2 X	> 637 psi	After 1 minute formed clay clumps with heavy packing on sides of bowl. After 2 minutes formed consistency of a cookie dough. Final product was a cake icing type consistency. WET MIX.

N/A Not available, material too wet to get a loose volume. Clay already in compacted state.

TABLE 3-31

SUMMARY OF WAC PHASE I MIXES
CLARIFIER SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1B	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash Type C Silica flour	400 g 20 g 1360 g 240 g	1 0.05 3.40 0.60	0.20	5.4 X	2.8 X	488 psi	After 30 seconds a heavy pack on sides of bowl formed and center of bowl was a clumpy soil. Final product was a dryish sticky cookie dough consistency. GOOD MIX, SLIGHT WET.
2B	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400 g 20 g 1088 g 192 g	1 0.05 2.72 0.48	0.25	N/A	2.6 X	>637 psi	After 15 seconds formed clumpy clay chunks approximately 1 inch in diameter, turned to bread dough, then to cake icing after 1 minute 30 seconds. Final product was a smooth, sticky cake icing. WET MIX.
3B	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400 g 20 g 907 g 106 g	1 0.05 2.26 0.26	0.30	N/A	2.3 X	>637 psi	Immediately turned to clay chunks and then quickly to bread dough. After 30 seconds, was consistency of sticky cake icing or cookie dough. Final product was a stiff, sticky, cake icing. WET MIX.
4B	Clarifier @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400 g 20 g 1190 g 210 g	1 0.05 2.97 0.52	0.20	5.4 X	3.8 X	0 psi	After 1 minute mixing, achieved a consistency of top soil or clumpy powder. Final product was a moist powder. DRY MIX.
5B	Clarifier @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400 g 20 g 952 g 168 g	1 0.05 2.38 0.42	0.25	N/A	2.7 X	>637 psi	At 30 seconds the side of bowl were packed and center contained moist powder which after 1 minute mixing became a friable soil or worm dirt consistency (clumpy soil). Final product was a dry stiff clay which resembled molding clay. GOOD MIX.

TABLE 3-31 (Continued)
SUMMARY OF WAC PHASE I MIXES
CLARIFIER SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
6B	Clarifier @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400 g 20 g 793 g 140 g	1 0.05 1.98 0.35	0.30	N/A	2.3 X	>637 psi	After 30 seconds of mixing, 1-inch diameter clay clumps formed which turned to bread dough after 1 minute. At 2 minutes, formed cake icing consistency. The final product resembled a sticky cake icing. WET MIX.
7B	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400 g 20 g 1054 g 186 g	1 0.05 2.63 0.46	0.20	5.8 X	3.6 X	0 psi	After 1 minute of mixing some packing on sides of bowl began but the center remained a moist powder. Final product was a moist powder. DRY MIX.
8B	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400 g 20 g 843 g 154 g	1 0.05 2.11 0.38	0.25	4.5 X	3.8 X	0 psi	One minute of mixing gave a mix which packed on sides of the bowl and center contained a moist powder. Final product was a moist powder. DRY MIX.
9B	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly Ash, Type C Silica flour	400 g 20 g 703 g 124 g	1 0.05 1.76 0.31	0.30	N/A	2.4 X	>637 psi	After mixing for 1 minute the sides of the bowl became packed with material. At 1.5 minutes medium curd, friable soil (worm dirt) formed. Final product was a dry clay. Able to break apart with little pressure. GOOD MIX, SLIGHTLY WET.

N/A - Not available, material too wet, to get a loose volume. Clay already in compacted state.

TABLE 3-32

SUMMARY OF WAC PHASE I MIXES
CLARIFIER SLUDGE (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48 Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1C	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash Type C Cement, Type I/II	400 g 20 g 1067 g 533 g	1 0.05 2.67 1.33	0.20	4.3 X	3.1 X	50 psi	Mix formed a moist powder with small clumps of dry material. Slight packing on sides of bowl with moist powder in center of bowl. Final product after 2.5 minutes mixing was a moist powder. DRY MIX.
2C	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 853 g 427 g	1 0.05 2.13 1.06	0.25	N/A	2.4 X	>637 psi	After 30 seconds of mixing produced large clay clumps which turned to bread dough after 1 minute. Final product after 2.5 minutes mixing produced a stiff clay. GOOD MIX, SLIGHTLY WET.
3C	Clarifier @ 20% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 711 g 356 g	1 0.05 1.78 0.89	0.30	N/A	1.7 X	444 psi	Immediately turned to cake icing and produced a final product of sloppy mud or a thick milkshake consistency. WET MIX.
4C	Clarifier @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 933 g 467 g	1 0.05 2.33 1.17	0.20	N/A	2.1 X	>637 psi	After 30 seconds formed a bread dough consistency which turned to a molding clay then to a final product of a thick cake icing. WET MIX.
5C	Clarifier @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 747 g 373 g	1 0.05 1.87 0.93	0.25	3.8 X	2.8 X	22 psi	This mix produced a moist powder with slight sticking to sides of bowl. Final product a moist powder. DRY MIX.
6C	Clarifier @ 30% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 622 g 311 g	1 0.05 1.55 0.78	0.30	N/A	2 X	>637 psi	After 1 minute of mixing, formed a friable soil (worm dirt) consistency (medium curd or chunks) after an additional 30 seconds became consistency of bread dough then a final consistency of very dry cookie dough or fudge. GOOD MIX.

TABLE 3-32 (Continued)
SUMMARY OF WAC PHASE I MIXES
CLARIFIER SLUDGE (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48 Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
7C	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 827 g 413 g	1 0.05 2.07 1.03	0.20	4.8 X	3.5 X	38 psi	This mix produced a final product with the consistency of a moist powder. DRY MIX.
8C	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 661 g 331 g	1 0.05 1.65 0.83	0.25	3.7 X	2.5 X	35 psi	This mix produced a final product with the consistency of a moist powder. DRY MIX.
9C	Clarifier @ 38.1% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 551 g 276 g	1 0.05 1.38 0.69	0.30	3.5 X	2.6 X	38 psi	This mix began to pack on sides of bowl after 30 seconds with the center of the mixing bowl having a consistency of a moist powder. The final product was a moist powder. DRY MIX.

N/A Not available, material too wet to get a loose volume. Clay is already in a compacted state.

TABLE 3-33

WAC PHASE I ANALYTICAL RESULTS
CLARIFIER MIXES (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1A-CLAR	#2A-CLAR	#3A-CLAR	#4A-CLAR	#5A-CLAR	#6A-CLAR	#7A-CLAR	#8A-CLAR	#9A-CLAR	#4Dup-CLAR[1]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0300108 P0300109	P0300110	P0300111 P0300112	P0300113 P0300114	P0300115	P0300116 P0300117	P0300118 P0300119	P0300120	P0300121 P0300122	P0301416
Date:				02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/17/95
W/P:				0.24	0.28	0.34	0.24	0.28	0.34	0.24	0.28	0.34	0.34
% Solids:				20	20	20	30	30	30	38.1	38.1	38.1	38.1
Analyte	Units												
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-134	pCi/L	3,510,000	12,800	< 5	NS	< 6	< 4	NS	< 7	NT	NS	NT	NT
Cs-137	pCi/L	111,000	737	< 5	NS	9.4 ± 2.2	4.3 ± 1.6	NS	8.1 ± 2.4	NT	NS	NT	NT
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Ra-226	pCi/L	117,000	415	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
U-233/234	pCi/L	35,200	254	1.9 ± 0.3	NS	3.1 ± 0.8	7.4 ± 0.8	NS	16 ± 4	720 ± 80	NS	970 ± 100	18 ± 2
U-235	pCi/L	1,410	10.2	0.11 ± 0.09	NS	<0.2	0.32 ± 0.06	NS	1.9 ± 1.4	29 ± 6	NS	43 ± 7	0.47 ± 0.31
U-238	pCi/L	24,500	177	2.0 ± 0.3	NS	2.6 ± 0.7	6.3 ± 0.7	NS	13 ± 4	810 ± 70	NS	790 ± 80	17 ± 2
Arsenic	mg/L	13.6	0.142	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Beryllium	mg/L	1.43	0.0142	<0.0007*	NS	<0.0007*	<0.0007*	NS	<0.0007*	0.74	NS	1.3	< 0.0005
Cadmium	mg/L	5.19	0.0518	0.053	NS	0.066	0.20	NS	0.23	19	NS	24	0.16
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Nitrate/ Nitrite	mg/L	15,900	166	57	NS	66	67	NS	100	140	NS	200	99
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2	2	NS	2	2
Final Leachate pH	Units	NA	NA	8.1	NS	8.6	8.3	NS	8.4	5.6	NS	5.4	8.3

TABLE 3-33 (Continued)
WAC PHASE I ANALYTICAL RESULTS
CLARIFIER MIXES (ADDITIVES: LIME AND FLY ASH)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1A-CLAR	#2A-CLAR	#3A-CLAR	#4A-CLAR	#5A-CLAR	#6A-CLAR	#7A-CLAR	#8A-CLAR	#9A-CLAR	#4Dup-CLAR[1]
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0300108 P0300109	P0300110	P0300111 P0300112	P0300113 P0300114	P0300115	P0300116 P0300117	P0300118 P0300119	P0300120	P0300121 P0300122	P0301416
Date:				02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/03/95	02/17/95
W/P:				0.24	0.28	0.34	0.24	0.28	0.34	0.24	0.28	0.34	0.34
% Solids:				20	20	20	30	30	30	38.1	38.1	38.1	38.1
Analyte	Units												
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0	NA
Bulk Density	g/cc	NA	NA	1.25	1.30	1.22	1.31	1.23	1.17	1.12	1.25	1.25	NA

(1) Field duplicate of 9A-CLAR; P0300122
NA Not applicable
NS Not submitted for analysis
NT Not tested for this analyte
* Result determined by a single-point method of standard additions

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

TABLE 3-34

WAC PHASE I ANALYTICAL RESULTS
CLARIFIER MIXES (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1WAC for Scenario 1		#1B-CLAR	#2B-CLAR	#3B-CLAR	#4B-CLAR	#5B-CLAR	#6B-CLAR	#7B-CLAR	#8B-CLAR	#9B-CLAR	#5Dup-CLAR(1)
Sample No.:				P0300676 P0300677	P0300678	P0300679 P0300680	P0300681 P0300682	P0300683	P0300684 P0300685	P0300686 P0300687	P0300688	P0300689 P0300690	P0301417
Date:		0.0068 in/yr Infiltration	1 in/yr Infiltration	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/17/95
W/P:				0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30	0.30
% Solids:				20	20	20	30	30	30	38.1	38.1	38.1	38.1
Analyte	Units												
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-134	pCi/L	3,510,000	12,800	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Cs-137	pCi/L	111,000	737	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Ra-226	pCi/L	117,000	415	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
U-233/234	pCi/L	35,200	254	27 ± 3	NS	130 ± 20	32 ± 4	NS	240 ± 30	230 ± 30	NS	460 ± 50	23 ± 3
U-235	pCi/L	1,410	10.2	0.89 ± 0.44	NS	5.1 ± 0.8	1.3 ± 0.4	NS	10 ± 1	8.0 ± 1	NS	22 ± 3	0.93 ± 0.46
U-238	pCi/L	24,500	177	24 ± 3	NS	110 ± 20	27 ± 3	NS	210 ± 30	200 ± 20	NS	390 ± 40	25 ± 3
Arsenic	mg/L	13.6	0.142	NT	NS	NS	NT	NS	NT	NT	NS	NT	NT
Beryllium	mg/L	1.43	0.0142	0.0027*	NS	0.048	0.025	NS	0.050	0.052	NS	0.25	0.0006*
Cadmium	mg/L	5.19	0.0518	3.5	NS	7.2	8.8	NS	12	12	NS	18	0.25
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT	NT
Nitrate/Nitrite	mg/L	15,900	166	51	NS	66	76	NS	95	100	NS	140	97
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2	2	NS	2	2
Final Leachate pH	Units	NA	NA	6.8	NS	6.1	6.3	NS	6.3	6.2	NS	6.0	8.2

TABLE 3-34 (Continued)
WAC PHASE I ANALYTICAL RESULTS
CLARIFIER MIXES (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1B-CLAR	#2B-CLAR	#3B-CLAR	#4B-CLAR	#5B-CLAR	#6B-CLAR	#7B-CLAR	#8B-CLAR	#9B-CLAR	#5Dup-CLAR(1)
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0300676 P0300677	P0300678	P0300679 P0300680	P0300681 P0300682	P0300683	P0300684 P0300685	P0300686 P0300687	P0300688	P0300689 P0300690	P0301417
Date:				02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/07/95	02/17/95
W/P:				0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30	0.30
% Solids:				20	20	20	30	30	30	38.1	38.1	38.1	38.1
Analyte	Units												
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0	NA
Bulk Density	g/cc	NA	NA	1.31	1.36	1.31	1.07	1.34	1.27	1.08	1.08	1.25	NA

(1) Field duplicate of 9B-CLAR; P0300690
NA Not applicable
NT Not tested for this analyte
NS Not submitted for analysis
* Result determined by a single-point method of standard additions

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

TABLE 3-35

WAC PHASE I ANALYTICAL RESULTS
CLARIFIER MIXES (ADDITIVES: LIME, FLY ASH AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		#1C-CLAR	#2C-CLAR	#3C-CLAR	#4C-CLAR	#5C-CLAR	#6C-CLAR	#7C-CLAR	#8C-CLAR	#9C-CLAR
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0300661 P0300662	P0300663	P0300664 P0300665	P0300666 P0300667	P0300668	P0300669 P0300670	P0300671 P0300672	P0300673	P0300674 P0300675
	Date:			02/06/95	02/06/95	02/06/95	02/06/95	02/06/95	02/06/95	02/06/95	02/06/95	02/06/95
	W/P:			0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30
	% Solids:			20	20	20	30	30	30	38.1	38.1	38.1
Analyte	Units											
Am-241	pCi/L	17,100	74.5	NT	NS	NT	NT	NS	NT	NT	NS	NT
Cs-134	pCi/L	3,510,000	12,800	NT	NS	NT	NT	NS	NT	NT	NS	NT
Cs-137	pCi/L	111,000	737	NT	NS	NT	NT	NS	NT	NT	NS	NT
Pu-239/240	pCi/L	1,070	4.43	NT	NS	NT	NT	NS	NT	NT	NS	NT
Ra-226	pCi/L	117,000	415	NT	NS	NT	NT	NS	NT	NT	NS	NT
U-233/234	pCi/L	35,200	254	330 ± 40	NS	690 ± 70	940 ± 100	NS	730 ± 80	580 ± 60	NS	870 ± 90
U-235	pCi/L	1,410	10.2	16 ± 4	NS	33 ± 6	39 ± 6	NS	28 ± 6	23 ± 5	NS	28 ± 5
U-238	pCi/L	24,500	177	290 ± 30	NS	630 ± 70	810 ± 80	NS	610 ± 70	500 ± 50	NS	710 ± 80
Arsenic	mg/L	13.6	0.142	NT	NS	NT	NT	NS	NT	NT	NS	NT
Beryllium	mg/L	1.43	0.0142	0.034	NS	1.6	1.9	NS	0.29	0.094	NS	0.42
Cadmium	mg/L	5.19	0.0518	4.9	NS	13	18	NS	12	8.8	NS	17
Chromium	mg/L	142	0.881	NT	NS	NT	NT	NS	NT	NT	NS	NT
Sodium	mg/L	1,750	14.9	NT	NS	NT	NT	NS	NT	NT	NS	NT
Nitrate/Nitrite	mg/L	15,900	166	50	NS	79	100	NS	100	92	NS	130
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2	2	NS	2
Final Leachate pH	Units	NA	NA	6.2	NS	5.2	5.3	NS	6.0	6.1	NS	5.9

TABLE 3-35 (Continued)
WAC PHASE I ANALYTICAL RESULTS
CLARIFIER MIXES (ADDITIVES: LIME, FLY ASH AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1 0.0068 in/yr Infiltration	WAC for Scenario 1 1 in/yr Infiltration	#1C-CLAR	#2C-CLAR	#3C-CLAR	#4C-CLAR	#5C-CLAR	#6C-CLAR	#7C-CLAR	#8C-CLAR	#9C-CLAR
Sample No.:				P0300661 P0300662	P0300663	P0300664 P0300665	P0300666 P0300667	P0300668	P0300669 P0300670	P0300671 P0300672	P0300673	P0300674 P0300675
Date:				02/06/95	02/06/95	02/06/95	02/06/95	02/06/95	02/06/95	02/06/95	02/06/95	02/06/95
W/P:				0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30
% Solids:				20	20	20	30	30	30	38.1	38.1	38.1
Analyte	Units											
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0	0	0	0
Bulk Density	g/cc	NA	NA	1.08	1.38	1.17	1.25	1.08	1.36	0.98	1.13	1.13

NA Not applicable
NT Not tested for this analyte
NS Not submitted for analysis
Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

Phase II involved a series of tests that were performed at the high and low W/P ratios identified from Phase I with different lime dosages to test compliance with leachability criteria. A summary of the mixes is provided in Table 3-36. The results of analyses are provided in Table 3-37. Graphs plotting TCLP extract concentrations versus extract pH are provided in Appendix G.

The TCLP leachate results provided in Table 3-37 for the Clarifier sludge are compared to the WACs. Two WACs are shown on Table 3-37, one is associated with the design infiltration rate of 0.0068 inches per year and the other is associated with a 1 inch per year infiltration rate. The development of the WACs are discussed in Appendix B.

All analytes leached at concentrations less than the design WAC concentrations. All analytes leached at concentrations less than the 1 inch per year WAC concentrations with the exception of sodium.

The figures provided in Appendix G indicate that the increase in the lime dosage from 5 percent to 7.5 percent resulted in an increase in the TCLP leachate pH. The leachate pH for the Phase II mixes ranged from 10.7 to 11.6 Standard Units (SU) as shown on Figure G-6A.

As shown on Table 3-37, the TCLP extracts for Phase II lime, cement, and fly ash mixes were analyzed for lead and nickel, which are LDR constituents associated with the hazardous waste codes for clarifier sludge. All LDR metals, including cadmium and chromium, leached at levels below their respective LDR standards.

3.4 207C AND CLARIFIER SLUDGE RESULTS

Testing on the 207C and Clarifier sludge required only a final phase evaluation. Preliminary and intermediate information was provided in an earlier section which discussed 207C and Clarifier testing independently.

3.4.1 Initial Characterization Data

A baseline evaluation was not submitted for combined 207C and Clarifier sludge.

3.4.2 Lime Addition Study Data

A lime addition study was not performed on the 207C and Clarifier sludge combined material.

TABLE 3-36

SUMMARY OF WAC PHASE II MIXES
CLARIFIER MIX
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P
1	Clarifier Sludge @ 20% Solids	400 g	1.0	0.2
	$Ca(OH)_2$	30 g	0.075	
	Fly Ash, Type C	1067 g	2.67	
	Cement, Type I/II	533 g	1.33	
2	Clarifier Sludge @ 20% Solids	400 g	1.0	0.3
	$Ca(OH)_2$	30 g	0.075	
	Fly Ash, Type C	711 g	1.78	
	Cement, Type I/II	356 g	0.89	
3	Clarifier Sludge @ 20% Solids	400 g	1.0	0.2
	$Ca(OH)_2$	30 g	0.075	
	Fly Ash, Type C	825 g	2.06	
	Cement, Type I/II	413 g	1.03	
4	Clarifier Sludge @ 20% Solids	400 g	1.0	0.3
	$Ca(OH)_2$	20 g	0.05	
	Fly Ash, Type C	550 g	1.375	
	Cement, Type I/II	275 g	0.69	
5	Clarifier Sludge @ 20% Solids	400 g	1.0	0.3
	$Ca(OH)_2$	30 g	0.075	
	Fly Ash, Type C	550 g	1.375	
	Cement, Type I/II	275 g	0.69	
6	Clarifier Sludge @ 20% Solids	400 g	1.0	0.3
	$Ca(OH)_2$	40 g	0.10	
	Fly Ash, Type C	550 g	1.375	
	Cement, Type I/II	275 g	0.69	

TABLE 3-37

WAC PHASE II ANALYTICAL RESULTS
CLARIFIER (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1 0.0068 in/yr Infiltration	WAC for Scenario 1 1 in/yr Infiltration	#1-CLAR	#2-CLAR	#3-CLAR	#4-CLAR	#5-CLAR	#6-CLAR
Sample No.:				P0304325 P0304326	P0304327 P0304328	P0304978 P0304979	P0304980 P0304981	P0304982 P0304983	P0304984 P0304985
Date:				03/21/95	03/21/95	03/22/95	03/22/95	03/22/95	03/22/95
W/P:				0.20	0.30	0.20	0.30	0.30	0.30
% Solids:				20.0	20.0	38.1	38.1	38.1	38.1
Analyte	Units								
Am-241	pCi/L	17,100	74.5	< 0.3	< 0.4	< 0.4	< 0.3	< 0.2	< 0.4
Cs-134	pCi/L	3,510,000	12,800	< 4	< 5	< 3	< 6	< 6	< 6
Cs-137	pCi/L	111,000	737	< 4	< 6	2.8 ± 1.3	< 7	< 6	5.8 ± 2.6
Pu-238	pCi/L	NA	NA	< 0.08	< 0.03	< 0.2	0.031 ± 0.035	< 0.2	< 0.03
Pu-239/240	pCi/L	1,070	4.43	< 0.03	< 0.09	< 0.03	< 0.03	0.099 ± 0.061	0.048 ± 0.042
Ra-226	pCi/L	117,000	415	1.1 ± 0.2	0.3 ± 0.1	< 0.2	0.4 ± 0.1	0.8 ± 0.2	1.1 ± 0.2
U-233/234	pCi/L	35,200	254	0.071 ± 0.053	0.041 ± 0.041	0.043 ± 0.042	< 0.08	0.084 ± 0.059	< 0.039 ± 0.039
U-235	pCi/L	1,410	10.2	< 0.08	< 0.03	< 0.08	< 0.03	< 0.03	< 0.032 ± 0.036
U-238	pCi/L	24,500	177	< 0.08	< 0.03	0.032 ± 0.036	< 0.08	< 0.08	< 0.03
Beryllium	mg/L	1.43	0.0142	< 0.0005	< 0.0005	< 0.0005	< 0.0006*	<0.0006*	< 0.0006*
Cadmium	mg/L	5.19	0.0518	< 0.005	< 0.005	0.005	0.005	< 0.005	0.007
Arsenic	mg/L	13.6	0.142	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Chromium	mg/L	142	0.881	0.19	0.14**	0.20	0.16	0.14	0.13
Nitrate/Nitrite	mg/L	15,900	166	26	39	81	120	120	120
Sodium	mg/L	1,750	14.9	240	280	370	460	470	480
Lead	mg/L	NA	NA	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

03-95-06/P

TABLE 3-37 (Continued)
WAC PHASE II ANALYTICAL RESULTS
CLARIFIER (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1 0.0068 in/yr Infiltration	WAC for Scenario 1 1 in/yr Infiltration	#1-CLAR	#2-CLAR	#3-CLAR	#4-CLAR	#5-CLAR	#6-CLAR
Sample No.:				P0304325 P0304326	P0304327 P0304328	P0304978 P0304979	P0304980 P0304981	P0304982 P0304983	P0304984 P0304985
Date:				03/21/95	03/21/95	03/22/95	03/22/95	03/22/95	03/22/95
W/P:				0.20	0.30	0.20	0.30	0.30	0.30
% Solids:				20.0	20.0	38.1	38.1	38.1	38.1
Analyte	Units								
Nickel	mg/L	NA	NA	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
TCLP Extraction Fluid	N/A	NA	NA	2	2	2	2	2	2
Final Leachate pH	Units	NA	NA	11.6	10.8	11.6	10.7	10.7	11.1
Paint Filter Liquids Test	mL	NA	NA	0	0	0	0	0	0

NA Not applicable
* Result determined by a single-point method of standard additions
** Presence of a possible matrix interference

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

3.4.3 Process Formulation Development Data

The information provided by the 207C mixes and Clarifier mixes was used to develop a formulation for the final evaluation of the material.

3.4.3.1 Pre-WAC Friable Mix Development

Information was obtained from individual material results. Combined 207C and Clarifier was not evaluated.

3.4.3.2 WAC Compliance Testing

Phase I. Combined 207C and Clarifier was not evaluated in this phase.

Phase II. A summary of the combined 207C and Clarifier sludge mixes is provided in Table 3-38. This testing was conducted at varying percent solids and only with the lime, fly ash, and cement additive. The analytical results are provided in Table 3-39.

The TCLP leachate results provided in Table 3-39 for the 207C and clarifier waste are compared to the WACs. Two WACs are shown on Table 3-29, one is associated with the design infiltration rate of 0.0068 inches per year and the other is associated with a 1 inch per year infiltration rate. The development of the WACs are discussed in Appendix B.

All analytes leached at concentrations less than the design WAC concentrations with the exception of sodium. All analytes also leached at concentrations less than the 1 inch per year WAC concentrations with the exception of arsenic, nitrate/nitrite, and sodium.

The figures provided in Appendix G indicate that the TCLP leachate pH for the Phase II mixes ranged from 11.6 to 11.9 SU, as shown on Figure G-7A. All of the analytes, with the exception of arsenic, nitrate/nitrite, and sodium, show a decrease in leachability as the pH of the leachate increases. Arsenic leaches at a fairly constant concentration, with the exception of one sample, at the pH values shown on Figure G-7J. This is a result of arsenic having amphoteric properties (i.e., soluble at low and high pHs). Arsenic is least soluble when the pH is in the neutral range. It should be noted that at the higher TCLP leachate pH ranges shown on Figure G-7J, the arsenic leachate concentration is less than the WAC for the design infiltration rate. Nitrate/nitrite and sodium show no dependency on pH.

TABLE 3-38

SUMMARY OF PHASE II MIXES
207C AND CLARIFIER
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Observations
1	207C/Clarifier Sludge @ 49% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	300 g 22.5 g 638 g 319 g	1.0 0.075 2.13 1.06	0.16	30 sec - Loose dirt, some small clumps 1 min - Loose, moist dirt 2 min - Moist dirt, few clumps 2.5 min - Dry powdery dirt, will clump if squeezed
2	207C/Clarifier Sludge @ 49% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	300 g 22.5 g 339 g 170 g	1.0 0.075 1.13 0.57	0.30	30 sec - Wet, cake icing 1 min - Thick, cake icing 2 min - Wet, milkshake 2.5 min - Wet, soft ice cream or thick milkshake
3	207C/Clarifier Sludge @ 73.6% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 30 g 440 g 220 g	1.0 0.075 1.10 0.55	0.16	30 sec - Small pebbles, gravel-like 1 min - Dry dirt with small pebbles 2 min - Dry dirt with some clumps 2.5 min - Dry loose soil, some small clumps
4	207C/Clarifier Sludge @ 73.6% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 20 g 234 g 117 g	1.0 0.05 0.59 0.29	0.30	30 sec - Dry small pebbles 1 min - Dry dirt with small pebbles 2 min - Moist clumping soil 2.5 min - Moist, friable soil - GOOD MIX
5	207C/Clarifier Sludge @ 73.6% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 30 g 234 g 117 g	1.0 0.075 0.59 0.29	0.30	30 sec - Dry with some small pebbles 1 min - Soil with some clumps 2 min - Dry clumping soil 2.5 min - Moist, friable soil
6	207C/Clarifier Sludge @ 73.6% Solids $Ca(OH)_2$ Fly Ash, Type C Cement, Type I/II	400 g 40 g 234 g 117 g	1.0 0.10 0.59 0.29	0.30	30 sec - Dry soil with pebbles 1 min - Soil, packing on sides 2 min - Dry, clumping soil 2.5 min - Moist, fine, loose soil

TABLE 3-39

WAC PHASE II ANALYTICAL RESULTS
207C AND CLARIFIER (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1 0.0068 in/yr Infiltration	WAC for Scenario 1 1 in/yr Infiltration	#1-207C/ CLAR	#2-207C/ CLAR	#3-207C/ CLAR	#4-207C/ CLAR	#5-207C/ CLAR	#6-207C/ CLAR
Sample No.:				P0304986 P0304987	P0304988 P0304989	P0304990 P0304991	P0304992 P0304993	P0304996 P0304997	P0304998 P0304999
Date:				03/22/95	03/22/95	03/22/95	03/22/95	03/22/95	03/22/95
W/P:				0.16	0.30	0.16	0.30	0.30	0.30
% Solids:				49.0	49.0	73.6	73.6	73.6	73.6
Analyte	Units								
Am-241	pCi/L	17,100	74.5	< 0.2	< 0.2	< 0.3	0.55 ± 0.18	< 0.3	< 0.2
Cs-134	pCi/L	3,510,000	12,800	< 6	< 7	< 6	< 4	< 6	< 5
Cs-137	pCi/L	111,000	737	< 6	< 6	< 7	< 5	< 7	< 5
Pu-238	pCi/L	NA	NA	< 0.07	< 0.04	< 0.2	< 0.03	< 0.2	< 0.03
Pu-239/240	pCi/L	1,070	4.43	< 0.08	< 0.2	< 0.04	0.032 ± 0.036	< 0.2	< 0.03
Ra-226	pCi/L	117,000	415	1.1 ± 0.2	0.3 ± 0.1	0.7 ± 0.1	0.4 ± 0.1	< 0.3	0.6 ± 0.1
U-233/234	pCi/L	35,200	254	0.073 ± 0.054	< 0.08	0.11 ± 0.07	0.092 ± 0.072	< 0.08	0.14 ± 0.08
U-235	pCi/L	1,410	10.2	< 0.08	< 0.1	< 0.08	< 0.04	< 0.03	< 0.08
U-238	pCi/L	24,500	177	0.073 ± 0.054	< 0.1	0.074 ± 0.055	0.092 ± 0.064	0.031 ± 0.036	0.16 ± 0.83
Beryllium	mg/L	1.43	0.0142	< 0.0006*	<0.0007*	<0.0008*	<0.0009*	<0.0009*	<0.0009*
Cadmium	mg/L	5.19	0.0518	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Arsenic	mg/L	13.6	0.142	0.1	< 0.1	0.1	0.2	0.2	0.2
Chromium	mg/L	142	0.881	0.18	0.16	0.18	0.16	0.17	0.17
Nitrate/Nitrite	mg/L	15,900	166	530	870	1,600	1,800	1,900	1,800
Sodium	mg/L	1,750	14.9	980	1,500	2,800	3,000	3,100	3,000

TABLE 3-39 (Continued)
WAC PHASE II ANALYTICAL RESULTS
207C AND CLARIFIER (ADDITIVES: LIME, FLY ASH, AND CEMENT)
POND SLUDGE TREATABILITY STUDY
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1 0.0068 in/yr Infiltration	WAC for Scenario 1 1 in/yr Infiltration	#1-207C/ CLAR	#2-207C/ CLAR	#3-207C/ CLAR	#4-207C/ CLAR	#5-207C/ CLAR	#6-207C/ CLAR
Sample No.:				P0304986 P0304987	P0304988 P0304989	P0304990 P0304991	P0304992 P0304993	P0304996 P0304997	P0304998 P0304999
Date:				03/22/95	03/22/95	03/22/95	03/22/95	03/22/95	03/22/95
W/P:				0.16	0.30	0.16	0.30	0.30	0.30
% Solids:				49.0	49.0	73.6	73.6	73.6	73.6
Analyte	Units								
Lead	mg/L	NA	NA	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/L	NA	NA	< 0.02	< 0.02	0.04	< 0.02	< 0.02	< 0.02
TCLP Extraction Fluid	N/A	NA	NA	2	2	2	2	2	2
Final Leachate pH	Units	NA	NA	11.8	11.8	11.9	11.6	11.7	11.9
Paint Filter Liquids Test	mL	NA	0	0	0	0	0	0	0

NA Not applicable
* Result determined by a single-point method of standard additions

Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/year infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

As shown on Table 3-39, the TCLP extracts for Phase II lime, cement, and fly ash mixes were analyzed for lead and nickel, which are LDR constituents associated with the hazardous waste codes for 207C/clarifier material. All LDR metals, including cadmium and chromium, leached at levels below their respective LDR standards.

4.0 PROCESS FORMULATION/OPERATING ENVELOPE

This section provides a discussion of the treatability study results and the development of an operating envelope for key process parameters. The development of a large operating envelope for key parameters will facilitate the operation of the treatment system under variable waste feed conditions.

The treatability study evaluated various formulations to determine which resulted in a product that produced a friable product that met all Waste Acceptance Criteria (WAC). Once it was determined that a specified formulation resulted in an acceptable end product, testing was conducted to develop an operating envelope that could be used during remediation. The operating envelope was developed to be conservative enough to ensure that all samples passed the required criteria.

Based on the treatability testing, several parameters appear to be the most significant regarding process control. These include the pozzolanic mixture composition, the ratio of water to pozzolans (W/P) in the process stream, and the solids/moisture content of the waste.

4.1 POND 207A/B SLUDGE

4.1.1 CSS Formulation

A treatment system consisting of the addition of hydrated lime, Type C fly ash, and Type I/II Portland cement is recommended for treating 207 A/B sludge. The hydrated lime is necessary to raise the pH to greater than 12 to stabilize the sludge and inhibit gas generation via biological decomposition of the organics in the waste, as well as to reduce the leachability of most metals and radionuclides. The cement and fly ash are required to eliminate the free water in the waste, achieve the WAC requirement for disposal in the OU4 closure, and to aid in the production of a friable product.

4.1.1.1 Fly Ash/Cement Ratio

The selected formulation for fly ash/cement is the same system investigated in 1992 for the production of monoliths for offsite disposal (HNUS, 1992c). The current treatability study for the production of a friable product, as well as the previous treatability study, both selected ratios of fly ash/cement of 2/1 as the desired operating ratio. The 1992 study investigated a wide range of fly ash/cement ratios (0/1 to 3.34/1) and concluded that the process performance was not sensitive to variations in the fly ash/cement ratio.

Small variations from the target fly ash/cement ratio of 2/1 are likewise not expected to cause any problems in meeting the WAC. The fly ash and cement do not need to be pre-blended, and can be fed separately at the 2 to 1 ratio.

Because the testing in the final phase was centered upon developing a range for the water to pozzolan (W/P) ratio and the solids loading, it was not considered necessary to develop a range for the fly ash to cement ratio. Therefore, all of the testing done in the final phase of the treatability study was conducted at a fly ash to cement ratio of 2 to 1.

4.1.1.2 Hydrated Lime Addition

A requirement for the treatment process is the addition of lime to inhibit biological activity. Lime is also used in the CSS formula to provide sufficient amounts of alkalinity to lower the solubility of most of the metals of concern. The solubility of many metals will remain low when the pH of the solution is alkaline, which results in successfully passing the WAC for protection of human health and the environment via the groundwater pathway. Although there are some metals which are amphoteric (solubility increases under acidic or alkaline conditions), such as arsenic, cadmium, chromium, and lead, no significant problems have been observed by maintaining sufficient amounts of alkalinity to maintain an alkaline pH in the TCLP extract.

In the final phase of testing, hydrated lime was added in a fixed percent (7.5 percent) by weight of raw waste. The addition of lime at this percentage resulted in a final leachate extract pH range of 10.9 to 11.8. Both hydrated lime and quicklime provide the desired pH adjustment, but hydrated lime was selected because it provided a more thorough mix with the waste material and did not generate excessive heat when added in large quantities.

Because of the importance of the addition of the lime for adjusting the pH of treated waste, which in turn controls the leachability of metals and radionuclides, a range of lime dosages was investigated. In the Phase II WAC confirmatory testing, the worst-case mix (assumed to be the mix with the highest water content in the raw waste and the highest W/P ratio) was tested at 5 percent and 10 percent lime dosages in addition to the target dosage of 7.5 percent. The data indicate that this variation of lime dosage around the target concentration of 7.5 percent has no appreciable effect on WAC compliance. Therefore, the treatment system should be able to tolerate this amount of variation from the target lime dosage.

Although lime often requires several minutes to fully dissolve into solution and react, this is not required for Pond 207 A/B sludge treatment since the curing time (at least 24 hours) is sufficient time to achieve the desired pH. The lime can be added to the treatment system at the same time that fly ash and cement are added.

4.1.2 Operating Range of Key Parameters

The waste loading of the raw waste, measured as the total solids content of the sludge, and the water-to-pozzolan (W/P) ratio of the treated waste (how much treatment additive is added as a percentage of the sludge water content) are the key parameters that control the operation of the treatment system. Figure 4-1 depicts the range of key operating parameters tested during the Phase II WAC compliance study.

4.1.2.1 Waste Loading (Percent Total Solids of Sludge)

The total solids content of the raw 207A/B sludge that will be delivered to the treatment system is largely a function of the material-handling properties of the sludge. Since the sludge is currently stored in 10,000-gallon tanks on the 750 pad, it must be extracted from the tanks and pumped to the treatment process. The sludge in the tanks has had water decanted from the surface, and is therefore probably approaching its terminal density. Previous studies estimated the terminal density to be approximately 15 percent total solids.

Based on this information, Phase I WAC testing was conducted at 10 percent, 20 percent, and 30 percent solids. The 10 percent solids content represents an assumed solids concentration if water needs to be added to dilute the sludge for pumping. The upper range is a worst-case scenario to increase the loading of metals and radionuclides for leachability testing. It must be noted that lower solids content sludges could also be treated by adding enough treatment additives to achieve the desired W/P ratios as discussed in Section 4.1.3.

4.1.2.2 Water to Pozzolan Ratio

The criteria determined to be the most critical for successful production of a friable product that meets all WAC is the water-to-pozzolan (W/P) ratio. Once the percent solids of the sludge entering the pug mill is determined, the weight of the water can be calculated. The quantity of pozzolans to be added is determined by dividing the weight of the water by the desired W/P ratio. For the purpose of testing during the treatability study, pozzolan was defined as fly ash plus cement in a ratio of 2:1.

The full-scale treatment system will operate within a water-to-pozzolan (W/P) ratio range that is capable of achieving a friable product. This range was determined during the pre-WAC testing phase and is estimated

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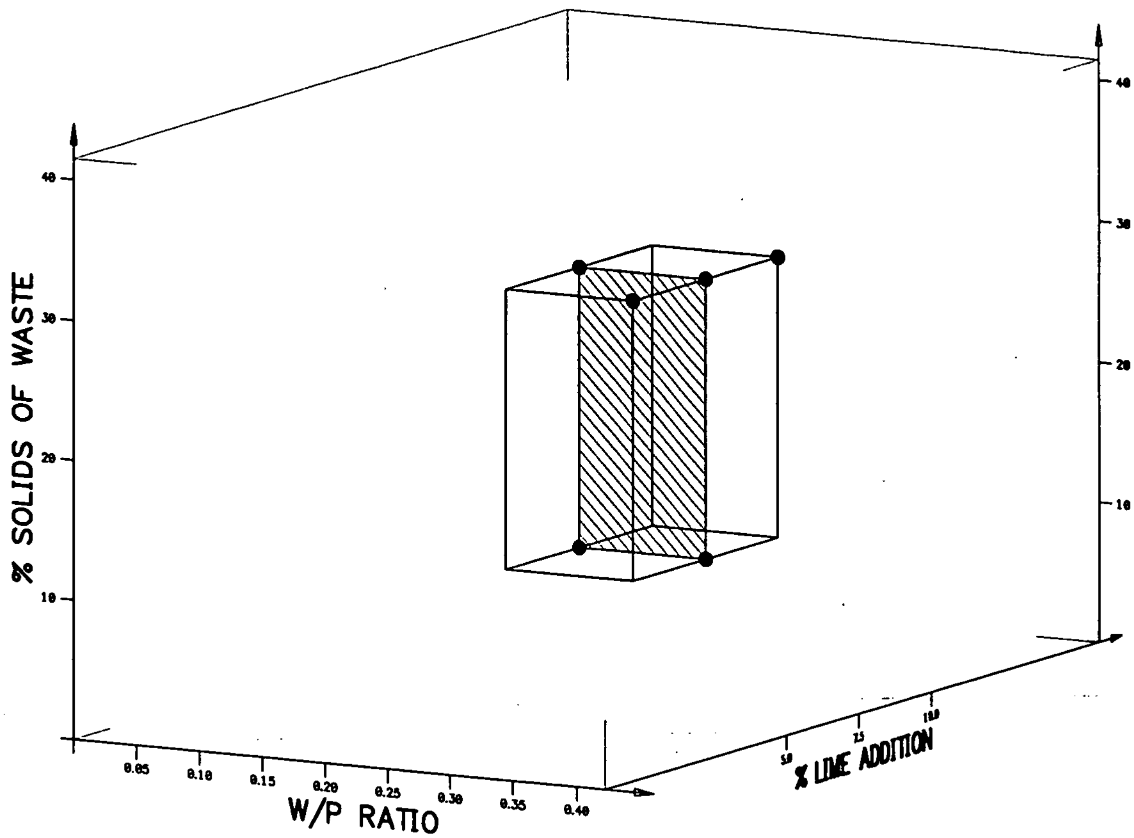

% SOLIDS	W/P	% LIME
10	0.2	7.5
10	0.3	7.5
30	0.2	7.5
30	0.3	5.0
30	0.3	7.5
30	0.3	10.0

207 A/B WASTE LOADING AND ADDITION VARIATION PROCESS RANGE FOR WAC PHASE II TESTING ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

FIGURE 4-1

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to be 0.22 to 0.27. For the purpose of defining a W/P range for WAC compliance, the friable product range was expanded to bracket the probable operating range. The low end of the range (0.20) is probably too dry for full-scale operation, whereas the high end (0.30) is probably too wet. However, if these extreme conditions meet the WAC, then any operating points in-between will also meet the WAC.

The Phase II WAC compliance testing showed that the WAC requirements could be met at W/P ratios between 0.20 and 0.30, notably no free liquids and leachate concentrations within an acceptable range. The percent solids tested during Phase II WAC compliance testing were 10 percent and 30 percent.

4.2 POND 207C MATERIAL

4.2.1 CSS Formulation

A treatment process consisting of the addition of hydrated lime, Type C fly ash, and Type I/II Portland cement is recommended for treating 207C sludge. The hydrated lime is necessary to raise the pH to greater than 12 to stabilize the sludge and inhibit gas generation via biological decomposition of the organics in the waste, as well as to reduce the leachability of most metals and radionuclides. The cement and fly ash are required to eliminate the free water in the waste, a WAC requirement for disposal in the OU4 closure, and to aid in the production of a friable product.

4.2.1.1 Fly Ash/Cement Ratio

The selected formulation for fly ash/cement is the same system investigated in 1992 for the production of monoliths for offsite disposal (HNUS, 1992b). The current treatability study for the production of a friable product, as well as the previous treatability study, both selected ratios of fly ash/cement of 2/1 as the desired operating ratio. The 1992 study investigated a wide range of fly ash/cement ratios (0/1 to 3.34/1) and concluded that the process performance was not sensitive to variations in the fly ash/cement ratio. Small variations from the target fly ash/cement ratio of 2/1 are likewise not expected to cause any problems in meeting the WAC. The fly ash and cement do not need to be pre-blended, and can be fed separately at the 2 to 1 ratio.

Because the testing in the final phase was centered upon developing a range for the water to pozzolan (W/P) ratio and the solids loading, it was not considered necessary to develop a range for the fly ash to cement ratio. Therefore, all of the testing done in the final phase of the treatability study was conducted at a fly ash to cement ratio of 2 to 1.

4.2.1.2 Hydrated Lime Addition

A requirement of the treatment process is the addition of lime to inhibit biological activity. Lime is also used in the CSS formula to provide sufficient amounts of alkalinity to lower the solubility of most of the metals of concern. The solubility of many metals will remain low when the pH of the solution is alkaline, which results in successfully passing the WAC for protection of human health and the environment via the groundwater pathway. Although there are some metals which are amphoteric (solubility increases under acidic or alkaline conditions) such as arsenic, cadmium, chromium, and lead, no significant problems have been observed by maintaining sufficient amounts of alkalinity to maintain an alkaline pH in the TCLP extract. It should be noted that sodium leached at concentrations which exceeded the WAC. Sodium leachate concentrations are independent of pH.

In the final phase of testing, hydrated lime was added in a fixed percent (7.5 percent) by weight of raw waste. The addition of lime at this percentage resulted in a final TCLP extract pH range of 11.8 to 12.0. Both hydrated lime and quicklime provided the desired pH adjustment, but hydrated lime was selected because it provided a more thorough mix with the waste material and did not generate excessive heat when added in large quantities.

Because of the importance of the addition of the lime for adjusting the pH of treated waste, which in turn controls the leachability of metals and radionuclides, a range of lime dosages was investigated. In the Phase II WAC confirmatory testing, the worst-case mix (assumed to be the mix with the highest water content in the raw waste and the highest W/P ratio) was tested at 5 percent and 10 percent lime dosages in addition to the target dosage of 7.5 percent. The data indicate that this variation of lime dosage around the target concentration of 7.5 percent has no appreciable effect on WAC compliance. Therefore, the treatment system should be able to tolerate this amount of variation from the target lime dosage.

Although lime often requires several minutes to fully dissolve into solution and react, this is not required for Pond 207C sludge treatment since the curing time (at least 24 hours) is sufficient time to achieve the desired pH. The lime can be added to the treatment system at the same time that fly ash and cement are added.

4.2.2 <u>Operating Range of Key Parameters</u>

The waste loading of the raw waste, measured as the total solids content of the sludge, and the water-to-pozzolan (W/P) ratio of the treated waste (how much treatment additive is added as a percentage of the sludge water content) are the key parameters that control the operation of the treatment system. Figure 4-2 depicts the range of key operating parameters tested during the Phase II WAC compliance study.

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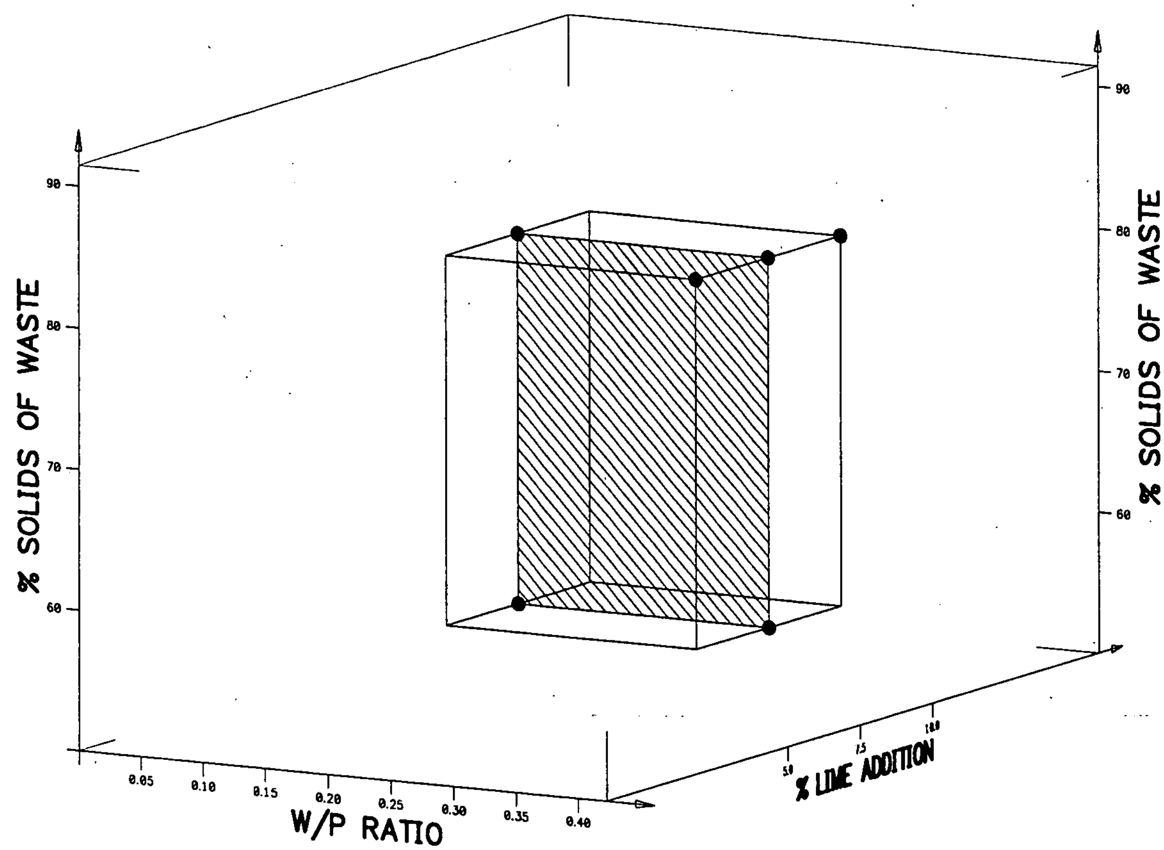

% SOLIDS	W/P	% LIME
56.3	0.15	7.5
56.3	0.35	7.5
82.5	0.15	7.5
82.5	0.35	5.0
82.5	0.35	7.5
82.5	0.35	10.0

207 C WASTE LOADING AND ADDITION VARIATION PROCESS RANGE FOR WAC PHASE II TESTING ROCKY FLATS, COLORADO

FIGURE 4-2

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4.2.2.1 Waste Loading (Percent Total Solids of Sludge)

The total solids content of the raw 207C sludge that will be delivered to the treatment system is largely a function of the material-handling properties of the sludge. Since the sludge is currently stored in 10,000-gallon tanks on the 750 pad, it must be extracted from the tanks and pumped to the treatment process.

Based on this information, Phase I WAC testing was conducted at specific gravities of 1.5, 1.75, and 1.98. The 1.5 specific gravity represents an assumed solids concentration if water needs to be added to dilute the sludge for pumping. The upper range is a worst-case scenario to increase the loading of metals and radionuclides for leachability testing. It must be noted that lower solids content sludges could also be treated by adding enough treatment additives to achieve the desired W/P ratios (see next section).

4.2.2.2 Water to Pozzolan Ratio

The criteria determined to be the most critical for successful production of a friable product that meets all WAC is the water-to-pozzolan (W/P) ratio. Once the percent solids of the sludge entering the pug mill is determined, the weight of the water can be calculated. The quantity of pozzolans to be added is determined by dividing the weight of the water by the desired W/P ratio. For the purpose of testing during the treatability study, pozzolan was defined as cement plus fly ash.

The full-scale treatment system will operate within a water-to-pozzolan (W/P) ratio range that is capable of achieving a friable product. This range was determined during the pre-WAC testing phase and is estimated to be 0.18 to 0.26. For the purpose of defining a W/P range for WAC compliance, the friable product range was expanded to bracket the probable operating range. The low end of the range, (0.15) is probably too dry for full-scale operation, whereas the high end (0.35) is probably too wet. However, if these extreme conditions meet the WAC, then any operating points in-between will also meet the WAC.

The Phase II WAC compliance testing showed that the WAC requirements could be met at W/P ratios between 0.15 and 0.35, notably no free liquids and leachate concentrations (with the exception of sodium) within an acceptable range. The specific gravity tested during Phase II WAC compliance testing were 1.5 and 2.0.

4.3 CLARIFIER SLUDGE

4.3.1 <u>CSS Formulation</u>

A treatment process consisting of the addition of hydrated lime, Type C fly ash, and Type I/II Portland cement is recommended for treating Clarifier sludge. The hydrated lime is necessary to raise the pH to greater than 12 to stabilize the sludge and inhibit gas generation via biological decomposition of the organics in the waste, as well as to reduce the leachability of most metals and radionuclides. The cement and fly ash are required to eliminate the free water in the waste, a WAC requirement for disposal in the OU4 closure, and to aid in the production of a friable product.

4.3.1.1 Fly Ash/Cement Ratio

The selected formulation for fly ash/cement is the same system investigated in 1992 for the production of monoliths for offsite disposal. (HNUS, 1992b). The current treatability study for the production of a friable product, as well as the previous treatability study, both selected ratios of fly ash/cement of 2/1 as the desired operating ratio. The 1992 study investigated a wide range of fly ash/cement ratios (0/1 to 3.34/1) and concluded that the process performance was not sensitive to variations in the fly ash/cement ratio. Small variations from the target fly ash/cement ratio of 2/1 are likewise not expected to cause any problems in meeting the WAC. The fly ash and cement do not need to be pre-blended, and can be fed separately at the 2 to 1 ratio.

Because the testing in the final phase was centered upon developing a range for the water-to-pozzolan (W/P) ratio and the solids loading, it was not considered necessary to develop a range for the fly ash to cement ratio. Therefore, all of the testing done in the final phase of the treatability study was conducted at a fly ash to cement ratio of 2 to 1.

4.3.1.2 Hydrated Lime Addition

A requirement of the treatment process is the addition of lime to inhibit biological activity. Lime is also used in the CSS formula to provide sufficient amounts of alkalinity to lower the solubility of most of the metals of concern. The solubility of many metals will remain low when the pH of the solution is alkaline, which results in successfully passing the WAC for protection of human health and the environment via the groundwater pathway. Although there are some metals which are amphoteric (solubility increases under acidic or alkaline conditions) such as arsenic, cadmium, chromium, and lead, no significant problems have been observed by maintaining sufficient amounts of alkalinity to maintain an alkaline pH in the TCLP extract.

In the final phase of testing hydrated lime was added in a fixed percent (7.5 percent) by weight of raw waste. The addition of lime at this percentage resulted in a final TCLP extract pH range of 10.7 to 11.6. Both hydrated lime and quicklime provided the desired pH adjustment, but hydrated lime was selected because it provided a more thorough mix with the waste material and did not generate excessive heat when added in large quantities.

Because of the importance of the addition of the lime for adjusting the pH of treated waste, which in turn controls the leachability of metals and radionuclides, a range of lime dosages was investigated. In the Phase II WAC confirmatory testing, the worst-case mix (assumed to be the mix with the highest water content in the raw waste and the highest W/P ratio) was tested at 5 percent and 10 percent lime dosages in addition to the target dosage of 7.5 percent. The data indicate that this variation of lime dosage around the target concentration of 7.5 percent has no appreciable effect on WAC compliance. Therefore, the treatment system should be able to tolerate this amount of variation from the target lime dosage.

Although lime often requires several minutes to fully dissolve into solution and react, this is not required for clarifier sludge treatment since the curing time (at least 24 hours) is sufficient time to achieve the desired pH. The lime can be added to the treatment system at the same time that fly ash and cement are added.

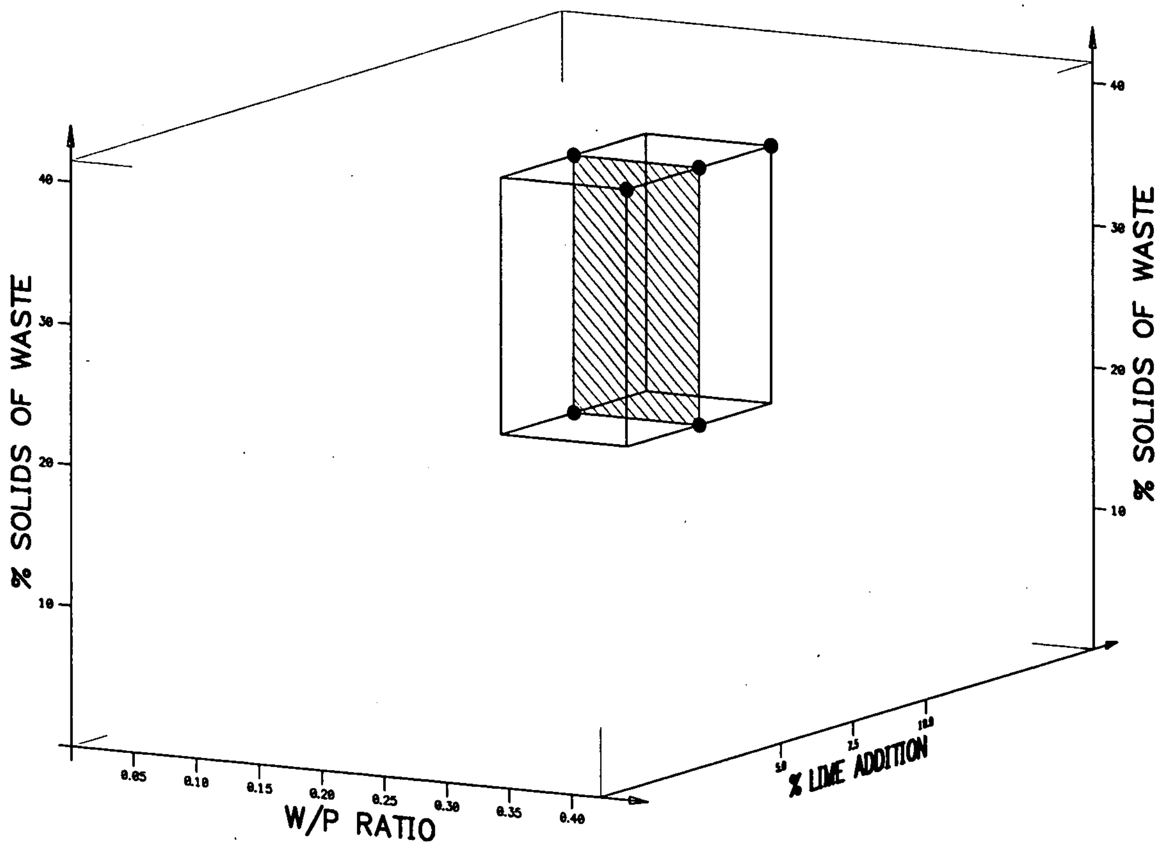
4.3.2 Operating Range of Key Parameters

The waste loading of the raw waste, measured as the total solids content of the sludge, and the water-to-pozzolan (W/P) ratio of the treated waste (how much treatment additive is added as a percentage of the sludge water content) are the key parameters that control the operation of the treatment system. Figure 4-3 shows graphically the range of key operating parameters tested during the Phase II WAC compliance study.

4.3.2.1 Waste Loading (Percent Total Solids of Sludge)

The total solids content of the raw clarifier sludge that will be delivered to the treatment system is largely a function of the material-handling properties of the sludge. Since the sludge will be stored in 10,000-gallon tanks on the 750 pad, it must be extracted from the tanks and pumped to the treatment process. The sludge will probably have water added to make it easier to pump from the clarifier, then water will be decanted from the surface after it is in the tanks. The sludge will then probably approach its terminal density.

Based on this information, Phase I WAC testing was conducted at 20 percent, 30 percent, and 38.1 percent solids. The 20 percent solids content represents an assumed solids concentration if water needs to be



% SOLIDS	W/P	% LIME
20	0.20	7.5
20	0.30	7.5
38.1	0.20	7.5
38.1	0.30	5.0
38.1	0.30	7.5
38.1	0.30	10.0

CLARIFIER SLUDGE WASTE LOADING AND ADDITION VARIATION PROCESS RANGE FOR WAC PHASE II TESTING ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

FIGURE 4–3

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added to dilute the sludge for pumping. The upper range is a worst-case scenario to increase the loading of metals and rationuclides for leachability testing. It must be noted that lower solids content sludges could also be treated by adding enough treatment additives to achieve the desired W/P ratios (see next section).

4.3.2.2 Water to Pozzolan Ratio

The criteria determined to be the most critical for successful production of a friable product that meets all WAC is the water-to-pozzolan (W/P) ratio. Once the percent solids of the sludge entering the pug mill is determined, the weight of the water can be calculated. The quantity of pozzolans to be added is determined by dividing the weight of the water by the desired W/P ratio. For the purpose of testing during the treatability study, pozzolan was defined as cement plus fly ash.

The full-scale treatment system will operate within a water-to-pozzolan (W/P) ratio range that is capable of achieving a friable product. This range was determined during the pre-WAC testing phase and is estimated to be 0.22 to 0.27. For the purpose of defining a W/P range for WAC compliance, the friable product range was expanded to bracket the probable operating range. The low end of the range (0.20) is probably too dry for full-scale operation, whereas the high end (0.30) is probably too wet. However, if these extreme conditions meet the WAC, then any operating points in between will also meet the WAC.

The Phase II WAC compliance testing showed that the WAC requirements could be met at W/P ratios between 0.20 and 0.30, notably, no free liquids and leachate concentrations within an acceptable range. The percent total solids tested during Phase II WAC compliance testing were 20 percent and 38.1 percent (as received).

4.4 COMBINED 207C/CLARIFIER SLUDGE

4.4.1 CSS Formulation

A treatment process consisting of the addition of hydrated lime, Type C fly ash, and Type I/II Portland cement is recommended for treating combined 207C/clarifier sludge. The hydrated lime is necessary to raise the pH to greater than 12 to stabilize the sludge and inhibit gas generation via biological decomposition of the organics in the waste, as well as to reduce the leachability of most metals and radionuclides. The cement and fly ash are required to eliminate the free water in the waste, a WAC requirement for disposal in the OU4 closure, and to aid in the production of a friable product.

4.4.1.1 Fly Ash/Cement Ratio

The selected formulation for fly ash/cement is the same system investigated in 1992 for the production of monoliths for offsite disposal (HNUS, 1992b). The current treatability study for the production of a friable product, as well as the previous treatability study, both selected ratios of fly ash/cement of 2/1 as the desired operating ratio. The 1992 study investigated a wide range of fly ash/cement ratios (0/1 to 3.34/1) and concluded that the process performance was not sensitive to variations in the fly ash/cement ratio. Small variations from the target fly ash/cement ratio of 2/1 are likewise not expected to cause any problems in meeting the WAC. The fly ash and cement do not need to be pre-blended, and can be fed separately at the 2 to 1 ratio.

Because the testing in the final phase was centered upon developing a range for the water to pozzolan (W/P) ratio and the solids loading, it was not considered necessary to develop a range for the cement to fly ash ratio. Therefore, all of the testing done in the final phase of the treatability study was conducted at a fly ash to cement ratio of 2 to 1.

4.4.1.2 Hydrated Lime Addition

A requirement of the treatment process is the addition of lime to inhibit biological activity. Lime is also used in the CSS formula to provide sufficient amounts of alkalinity to lower the solubility of most of the metals of concern. The solubility of many metals will remain low when the pH of the solution is alkaline, which results in successfully passing the WAC for protection of human health and the environment via the groundwater pathway. Although there are some metals which are amphoteric (solubility increases under acidic or alkaline conditions) such as arsenic, cadmium, chromium, and lead, no significant problems have been observed by maintaining sufficient amounts of alkalinity to maintain an alkaline pH in the TCLP extract. It should be noted that sodium leached at concentrations which exceeded the WAC. Sodium leachate concentration is inherently independent of pH.

In the final phase of testing, hydrated lime was added in a fixed percent (7.5 percent) by weight of raw waste. The addition of lime at this percentage resulted in a final TCLP extract pH range of 11.7 to 11.9. Both hydrated lime and quicklime provided the desired pH adjustment, but hydrated lime was selected, because it provided a more thorough mix with the waste material and did not generate excessive heat when added in large quantities.

Because of the importance of the addition of the lime for adjusting the pH of treated waste, which in turn controls the leachability of metals and radionuclides, a range of lime dosages was investigated. In the

Phase II WAC confirmatory testing, the worst-case mix (assumed to be the mix with the highest water content in the raw waste and the highest W/P ratio) was tested at 5 percent and 10 percent lime dosages in addition to the target dosage of 7.5 percent. The data indicate that this variation of lime dosage around the target concentration of 7.5 percent has no appreciable effect on WAC compliance. Therefore, the treatment system should be able to tolerate this amount of variation from the target lime dosage.

Although lime often requires several minutes to fully dissolve into solution and react, this is not required for combined 207C/Clarifier sludge treatment since the curing time (at least 24 hours) is sufficient time to achieve the desired pH. The lime can be added to the treatment system at the same time that the fly ash and cement are added.

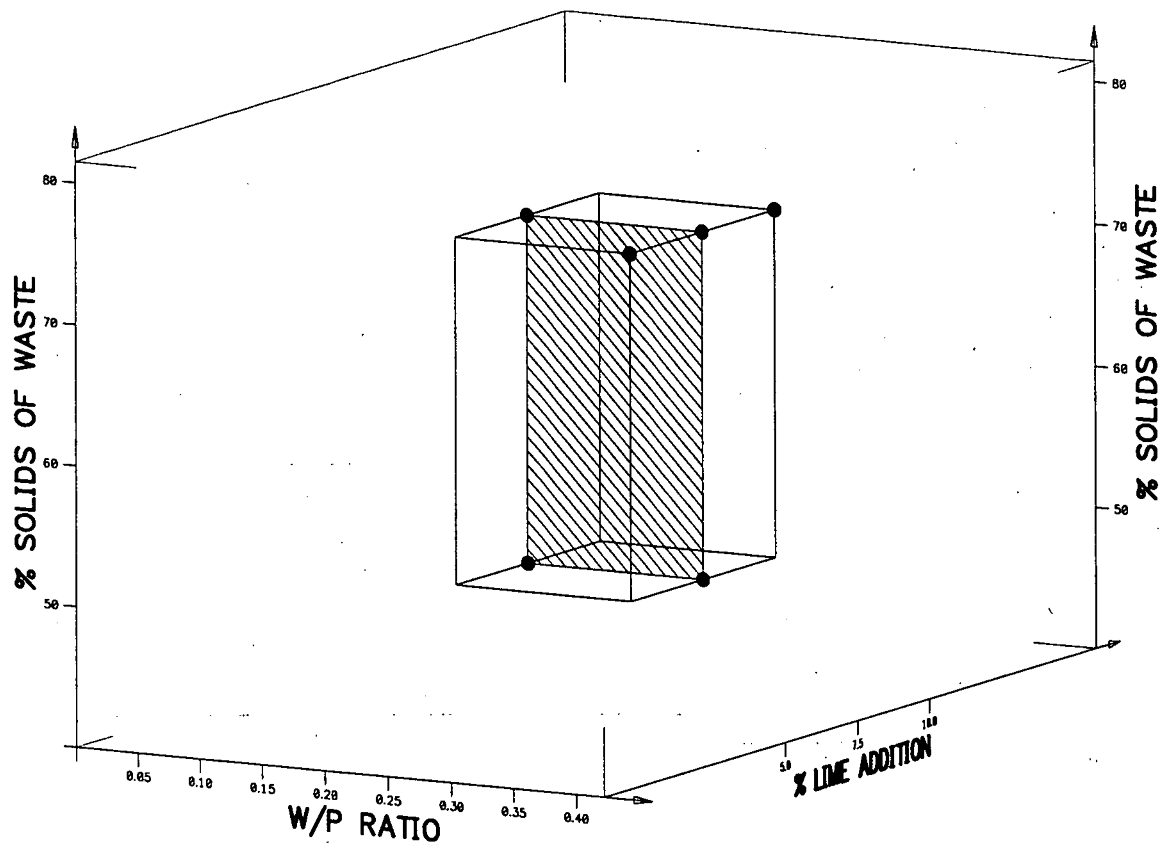
4.4.2 Operating Range of Key Parameters

The waste loading of the raw waste, measured as the total solids content of the sludge, and the water-to-pozzolan (W/P) ratio of the treated waste (how much treatment additive is added as a percentage of the sludge water content) are the key parameters that control the operation of the treatment system. Figure 4-4 depicts the range of key operating parameters tested during the Phase II WAC compliance study.

4.4.2.1 Waste Loading (Percent Total Solids of Sludge)

The total solids content of the raw combined 207C/Clarifier sludge that will be delivered to the treatment system is largely a function of the material-handling properties of the sludge. Since the sludge will be stored in 10,000-gallon tanks on the 750 pad at the time of processing, it must be extracted from the tanks and pumped to the treatment process. The clarifier sludge portion will probably require water to be added to make it easier to pump from the clarifier, then water will be decanted from the surface after it has been transferred to the tanks.

Based on this information, Phase II WAC testing was conducted at 49 percent and 73.6 percent solids. The 49 percent solids content represents an assumed solids concentration if water needs to be added to dilute the sludge for pumping. The upper range is a worst-case scenario to increase the loading of metals and rationuclides for leachability testing. It must be noted that lower solids content sludges could also be treated by adding enough treatment additives to achieve the desired W/P ratios.



% SOLIDS	W/P	% LIME
49	0.16	7.5
49	0.30	7.5
73.6	0.16	7.5
73.6	0.30	5.0
73.6	0.30	7.5
73.6	0.30	10.0

207C AND CLARIFIER SLUDGE WASTE LOADING AND ADDITIVES ADDITION VARIATION PROCESS RANGE FOR WAC PHASE II TESTING ROCKY FLATS, COLORADO

FIGURE 4–4

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4.4.2.2 Water to Pozzolan Ratio

The criteria determined to be the most critical for successful production of a friable product that meets all WAC is the water-to-pozzolan (W/P) ratio. Once the percent solids of the sludge entering the pug mill is determined, the weight of the water can be calculated. The quantity of pozzolans to be added is determined by dividing the weight of the water by the desired water to pozzolan ratio. For the purpose of testing during the treatability study, pozzolan was defined as cement plus fly ash.

The full-scale treatment system will operate within a water-to-pozzolan (W/P) ratio range that is capable of achieving a friable product. This range was determined during the WAC testing phase to be 0.18 to 0.26. For the purpose of defining a W/P range for WAC compliance, the friable product range was expanded to bracket the probable operating range. It is assumed that the low end of the range (0.16) is probably too dry for full-scale operation, whereas the high end (0.30) is probably too wet. However, if these extreme conditions meet the WAC, then any operating points in-between will also meet the WAC.

The Phase II WAC compliance testing showed that the WAC requirements could be met at W/P ratios between 0.16 and 0.30, notably, no free liquids and leachate concentrations (with the exception of sodium) within an acceptable range. The percent total solids tested during Phase II WAC compliance testing were 49 percent and 73.6 percent.

5.0 CONCLUSIONS

The objective of the treatability study was to develop a treatment system for Pond 207A/B sludges, Pond 207C waste, and Clarifier sludge such that the treated wastes meet the waste acceptance criteria for disposal in the OU4 closure. The following sections summarize the conclusions of the treatability study for each of the waste materials investigated.

5.1 207A/B SLUDGE

Following are the conclusions of the treatability study conducted on the combined sludges from the 207A and the 207B series ponds.

5.1.1 Formulation

The CSS formulation selected for the 207A/B sludge includes hydrated lime, Type C fly ash, and Type I/II Portland cement. The lime is added at 7.5% by weight of the untreated waste. The fly ash and cement are combined in a 2 to 1 fly ash to cement ratio, and are added at a rate determined by the desired water to pozzolan ratio.

5.1.2 Water-to-Pozzolan Ratio

Compliance with waste acceptance criteria was achieved at water-to-pozzolan ratios from 0.2 to 0.3. The optimum range for achieving a friable product is a subset of this range, at water-to-pozzolan ratios from 0.22 to 0.27.

5.1.3 Waste Loading

The treatability study testing was conducted on sludges with total solids concentrations that ranged from 10% to 30% total solids which brackets the material as it currently exists onsite. The treatability study results indicate that the proposed stabilization formula will produce a final product that meets the Waste Acceptance Criteria if the waste loading is within the above range.

5.1.4 Waste Acceptance Criteria and Performance Standard Compliance

Based on the results of the treatability study, it is concluded that the treatment process will meet all applicable Waste Acceptance Criteria (with the exception of the total volume of treated waste) if the system is operated within the stated formulation, water-to-pozzolan ratio, and waste loading ranges. Specific WAC requirements were addressed by the treatability study as follows:

- The treatment is the minimum needed to meet all WAC.
- The treated waste will not contain free liquids as measured by the Paint Filter Liquids Test, Method 9095 (SW 1992).
- The treated waste will be in particulate form, not a monolith. The particle size will be less than 3 inches and will not tend to agglomerate when the system is operated on the drier end of the water-to-pozzolan range.
- The treated waste will not agglomerate into particles greater than 3 inches when mixed with site soil.
- The treated waste will be resistant to dispersion by wind. The conceptual design of the treatment system uses a screen to capture any fine particles and recycle them back into the treatment process. This design will allow the system to operate at the dry end of the water-to-pozzolan range.
- The treated waste will have a pH of 12 or greater, which is sufficient to inhibit the biological degradation of any organics. The lack of biological activity will reduce the potential for gas generation.
- The volume of the treated waste, when added to the volumes of the other treated wastes, may slightly exceed 20,000 cy.
- The leachate will not contain any of the constituents of concern at concentrations that are not protective of human health and the environment. This is based on comparison of TCLP leach data with values predicted by a contaminant transport model using the design infiltration rate of 0.0068 inch per year for the OU4 closure. It is also noted that the leachate complies with the LDR standards applicable to pond sludge.

5.2 207C WASTE

Following are the conclusions of the treatability study conducted on the Pond 207C waste.

5.2.1 Formulation

The CSS formulation selected for the 207C waste includes hydrated lime, Type C fly ash, and Type I/II Portland cement. The lime is added at 7.5% by weight of the untreated waste. The fly ash and cement are combined in a 2 to 1 fly ash to cement ratio, and are added at a rate determined by the desired water-to-pozzolan (W/P) ratio.

5.2.2 Water-to-Pozzolan Ratio

Compliance with waste acceptance criteria was achieved at W/P ratios from 0.15 to 0.35. The optimum range for achieving a friable product is a subset of this range, at W/P ratios from 0.18 to 0.26.

5.2.3 Waste Loading

The treatability study testing was conducted on waste with total solids concentrations ranging from 56.3% to 82.5%, which corresponds to a range of specific gravity of 1.5 to 2.0. The treatability study results indicate that the proposed stabilization formula will produce a final product that meets the Waste Acceptance Criteria (with the exception of the leachate concentration for sodium) if the waste loading is within the above range.

5.2.4 Waste Acceptance Criteria Compliance

Based on the results of the treatability study, it is concluded that the treatment process will meet all applicable Waste Acceptance Criteria (with the exception of the total volume of treated waste and the leachate concentration of sodium) if the system is operated within the stated formulation, water-to-pozzolan ratio, and waste loading ranges. Specific WAC requirements were addressed by the treatability study as follows:

- The treatment is the minimum needed to meet all WAC.

- The treated waste will not contain free liquids as measured by the Paint Filter Liquids Test, Method 9095 (SW 1992).

- The treated waste will be in particulate form, not a monolith. The particle size will be less than 3 inches and will not tend to agglomerate when the system is operated on the drier end of the water-to-pozzolan range.

- The treated waste will not agglomerate into particles greater than 3 inches when mixed with site soil.

- The treated waste will be resistant to dispersion by wind. The conceptual design of the treatment system uses a screen to capture any fine particles and recycle them back into the treatment process. This design will allow the system to operate at the dry end of the water-to-pozzolan range.

- The treated waste will have a pH of 12 or greater, which is sufficient to inhibit the biological degradation of any organics. The lack of biological activity will reduce the potential for gas generation.

- The volume of the treated waste, when added to the volumes of the other treated wastes, may slightly exceed 20,000 cy.

- The leachate will not contain any of the constituents of concern, with the exception of sodium, at concentrations that are not protective of human health and the environment. This is based on comparison of TCLP leach data with values predicted by a contaminant transport model using the design infiltration rate of 0.0068 inch per year for the OU4 closure. It is also noted that the leachate complies with the LDR standards applicable to pond sludge.

5.3 CLARIFIER SLUDGE

Following are the conclusions of the treatability study conducted on the clarifier sludge.

5.3.1 Formulation

The CSS formulation selected for the clarifier sludge includes hydrated lime, Type C fly ash, and Type I/II Portland cement. The lime is added at 7.5% by weight of the untreated waste. The fly ash and cement are combined in a 2 to 1 fly ash to cement ratio, and are added at a rate determined by the desired water to pozzolan ratio.

5.3.2 Water-to-Pozzolan Ratio

Compliance with waste acceptance criteria was achieved at water-to-pozzolan ratios (W/P) from 0.20 to 0.30. The optimum range for achieving a friable product is a subset of this range, at W/P ratios from 0.22 to 0.27.

5.3.3 Waste Loading

The treatability study testing was conducted on sludges with total solids concentrations that ranged from 20% to 38.1%. The treatability study results indicate that the proposed stabilization formula will produce a final product that meets the waste acceptance criteria if the waste loading is within the above range.

5.3.4 Waste Acceptance Criteria Compliance

Based on the results of the treatability study, it is concluded that the treatment process will meet all applicable Waste Acceptance Criteria (with the exception of the total volume of treated waste) if the system is operated within the stated formulation, W/P ratio and waste loading ranges. Specific WAC requirements were addressed by the treatability study as follows:

- The treatment is the minimum needed to meet all WAC.

- The treated waste will not contain free liquids as measured by the Paint Filter Liquids Test, Method 9095 (SW 1992).

- The treated waste will be in particulate form, not a monolith. The particle size will be less than 3 inches and will not tend to agglomerate when the system is operated on the drier end of the water-to-pozzolan range.

- The treated waste will not agglomerate into particles greater than 3 inches when mixed with site soil.

- The treated waste will be resistant to dispersion by wind. The conceptual design of the treatment system uses a screen to capture any fine particles and recycle them back into the treatment process, which will allow the system to operate at the dry end of the water-to-pozzolan range.

- The treated waste will have a pH of 12 or greater, which is sufficient to inhibit the biological degradation of any organics. The lack of biological activity will reduce the potential for gas generation.

- The volume of the treated waste, when added to the volumes of the other treated wastes, may slightly exceed 20,000 cy.

- The leachate will not contain any of the constituents of concern at concentrations that are not protective of human health and the environment. This is based on comparison of TCLP leach data with values predicted by a contaminant transport model using the design infiltration rate of 0.0068 inch per year for the OU4 closure. It is also noted that the leachate complies with the LDR standards applicable to pond sludge.

5.4 COMBINED 207C/CLARIFIER WASTE

Treatability testing was performed on a mix of 207C waste (80%) and clarifier sludge (20%). This was a precaution in case the clarifier sludge could not be treated alone and meet the WAC, and needed to be diluted. Following are the conclusions of the treatability study conducted on the combined 207C/clarifier waste.

5.4.1 Formulation

The CSS formulation selected for the Clarifier/207C sludge includes hydrated lime, Type C fly ash, and Type I/II Portland cement. The lime is added at 7.5% by weight of the untreated waste. The fly ash and cement are combined in a 2 to 1 fly ash to cement ratio and are added at a rate determined by the desired water-to-pozzolan (W/P) ratio.

5.4.2 Water-to-Pozzolan Ratio

Compliance with waste acceptance criteria was achieved at water-to-pozzolan ratios from 0.16 to 0.30. The optimum range for achieving a friable product is a subset of this range, at W/P ratios from 0.18 to 0.26.

5.4.3 Waste Loading

The treatability study testing was conducted on sludges with total solids concentrations that ranged from 49% to 73.6%. The treatability study results indicate that the proposed stabilization formula will produce a final product that meets the Waste Acceptance Criteria (with the exception of the leachate concentration for sodium) if the waste loading is within the above range.

5.4.4 Waste Acceptance Criteria Compliance

Based on the results of the treatability study, it is concluded that the treatment process will meet all applicable Waste Acceptance Criteria (with the exception of the total volume of treated waste and the leachate concentration of sodium) if the system is operated within the stated formulation, water-to-pozzolan ratio, and waste loading ranges. Specific WAC requirements were addressed by the treatability study as follows:

- The treatment is the minimum needed to meet all WAC.

- The treated waste will not contain free liquids as measured by the Paint Filter Liquids Test, Method 9095 (SW 1992).

- The treated waste will be in particulate form, not a monolith. The particle size will be less than 3 inches and will not tend to agglomerate when the system is operated on the drier end of the water-to-pozzolan range.

- The treated waste will not agglomerate into particles greater than 3 inches when mixed with site soil.

- The treated waste will be resistant to dispersion by wind. The conceptual design of the treatment system uses a screen to capture any fine particles and recycle them back into the treatment process, which will allow the system to operate at the dry end of the water-to-pozzolan range.

- The treated waste will have a pH of 12 or greater, which is sufficient to inhibit the biological degradation of any organics. The lack of biological activity will reduce the potential for gas generation.

- The volume of the treated waste, when added to the volumes of the other treated wastes, may slightly exceed 20,000 cy.

- The leachate will not contain any of the constituents of concern at concentrations, with the exception of sodium, that are not protective of human health and the environment. This is based on comparison of TCLP leach data with values predicted by a contaminant transport model using the design infiltration rate of 0.0068 inch per year for the OU4 closure. It is also noted that the leachate complies with the LDR standards applicable to pond sludge.

5.5 SUMMARY

The CSS formulation developed for the pond sludges meets all of the goals of the treatability study. Following is a summary of the major conclusions of this treatability study:

- The treatment system is able to meet all waste acceptance criteria with the exception of total volume of treated waste, and the leachate concentration of sodium for 207C waste.

- The formulation developed for the pond sludges relies on the addition of a blend of fly ash and cement to eliminate the free water. Hydrated lime is added to the waste to reduce the potential for biological decomposition of any organics and to achieve maximum reduction of leachability of most metals and radionuclides of concern by raising the pH.

- The treatment system produces a friable product, which is a more desirable final product than a monolith. The friable product can be transported directly to the OU4 closure area for disposal, whereas a monolith would require additional processing (i.e., shredder/crusher) before disposal. The final product is not extremely sensitive to curing temperature and can be exposed to freezing temperature within 24 hours after mixing.

- The rapid curing of the treated waste, and thus the rapid compliance with the WAC, minimizes the staging area requirements for the treatment system. A curing time of 24 hours is sufficient before placement in the OU4 closure can occur. The treated pond and clarifier sludge should be protected from freezing during this curing period.

- A single formulation of lime, fly ash, and cement was developed for all three pond sludges (also the same formulation for treatment of pondcrete). This enhances the operability of the system. Only minor adjustments of the pozzolan addition based on the water content of the waste material is required.

The process operating ranges of key parameters for treatment of pond and clarifier sludges is as follows:

- <u>208 A/B Sludge</u>
  - Waste loading total solids: . . . . 10% to 30%
  - Water-to-pozzolan ratio tested that met WAC: . . . . 0.20 to 0.30
  - Water-to-pozzolan ratio that produces a friable product: . . . 0.22 to 0.27
  - Lime addition by weight of waste feed: . . . . 7.5% ± 2.5%

- 207C Waste
  - Waste loading total solids: .... 56.3% to 82.5%
  - Water-to-pozzolan ratio tested that met WAC: .... 0.15 to 0.35
  - Water-to-pozzolan ratio that produces a friable product: ... 0.18 to 0.26
  - Lime addition by weight of waste feed: .... 7.5% ± 2.5%

- Clarifier Sludge
  - Waste loading total solids: .... 20% to 38.1%
  - Water-to-pozzolan ratio tested that met WAC: .... 0.20 to 0.30
  - Water-to-pozzolan ratio that produces a friable product: ... 0.22 to 0.27
  - Lime addition by weight of waste feed: .... 7.5% ± 2.5%

- Combined 207C/Clarifier Sludge
  - Waste loading total solids: .... 49% to 73.6%
  - Water-to-pozzolan ratio tested that met WAC: .... 0.16 to 0.30
  - Water-to-pozzolan ratio that produces a friable product: ... 0.18 to 0.26
  - Lime addition by weight of waste feed: .... 7.5% ± 2.5%

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APPENDIX A

EQUIPMENT RECOMMENDATION REPORT

POND SLUDGE EQUIPMENT RECOMMENDATION REPORT

The Conceptual Design Report (CDR) team in cooperation with the treatability study has developed an equipment list for the pond sludge processing train. The equipment list is provided in Table A-1. Throughout the course of the treatability study, physical and chemical properties of the pond wastes and of the final, friable product have been measured and observations noted. These data, combined with the applicable data/results from past treatability and characterization studies, were used to evaluate the compatibility of the recommended equipment, pond sludge wastes, and additives. Also, physical properties of the friable product were considered during the selection of the materials handling equipment. All equipment selected for the process train are capable of handling a wide range of physical properties. Upon review of the equipment selected and the properties of the wastes and products, no vendor-specific equipment will be required. All equipment is of the "off-the-shelf" type. However, the equipment list does provide a vendor specific listing of equipment to finalize the design and equipment lay-out and arrangement drawings. Following is a brief discussion of the major unit operations and equipment.

Pond Sludge Transfer From the Interim Storage Tanks

The pond sludge transfer unit process operation system consists of a vacuum pump and a progressive cavity pump. The use of an "off-the-shelf" type of vacuum system is not precluded by the chemical or physical properties of the sludges. However, specific design criteria are specified within the CDR.

Treatment Additives Storage and Feed

The treatment additives storage and feed unit process operation consists of bulk storage silos, rotary valve feeders, weigh-belt conveyors, and screw conveyors. This equipment is routinely used to store and feed dry bulk reagents, such as pozzolans and lime. These common additives (cement, fly ash, and lime) have no characteristics that preclude the use of commonly available, "off-the-shelf" type of equipment for this unit operation.

Pond Sludge Mixing/Blending Treatment With Additives

The pond sludge mixing/blending treatment unit process operation consists of a pug mill. Pug mills are commonly used for a mixing/blending process such as that contained in the pond sludge operations. The pug mill will produce the product in a friable soil-like consistency. The use of an "off-the-shelf" type of pug mill is not precluded by the additives or waste. However, specific design criteria are specified within the CDR.

Treated Waste Screening and Recycling of Undersized Treated Waste

The treated waste screening unit process operation consists of a recycle stream to avoid the production of excessive fines in the final product, which would violate the WAC. The fines, which are mainly excess pozzolans, will be recycled. The physical and chemical properties of the final product would not preclude the use of common off-the-shelf screening equipment that meets the design specifications as described in the CDR.

Treated Waste Storage and Testing

The equipment specified within the treated waste storage and testing unit process operation is roll-off type containers with removable covers. These containers are commonly used to transport soil-like materials. The potential for dusting will be controlled with the use of covers. The final product, being a friable soil-like material, will have minimal dusting properties as specified in the WAC. These containers will also be used for the treated waste transfer to the OU4 closure area. Upon consideration of the physical and chemical properties of the final product, no specialized containers will be needed.

Dust Emissions Control

The dust emissions control unit process consists of air collection manifolds, air transfer duct work, a baghouse-type dust collector, a centrifugal type exhaust blower, and a High-Efficiency Particulate Air (HEPA) exhaust filter. This equipment is routinely used to control particulate emissions from dry bulk feeding and storage facilities, such as pozzolans and lime. The pond sludges and additives exhibit no characteristics that preclude the use of commonly available, "off-the-shelf" type of equipment for this unit operation.

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST

AREA 1000: SLUDGE REMOVAL AND TRANSFER UNIT (SRTU)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
VTS-1001	Sludge Removal System	1	Self-contained mobile wet-dry vacuum system equipped with: - One 3,000 cfm @ 15" Hg vacuum pump with 500 to 1000 lbs/min handling capacity - One 100 ft^3, 60° cone-bottomed discharge hopper with bottom slide-gate isolation valve - One manually-operated discharge control valve (pinch) - One HEPA filter on vacuum pump discharge	Hi-Vac Model 2100, with 100 ft^3 cone-bottomed intercept hopper, slide-gate and discharge control valve. Equipped with four 24" x 24" x 12", 1000 cfm HEPA filter elements, three operating, one standby.	100	New Purchase
P-1001	Sludge Transfer Pump	1	Progressive-cavity, positive-displacement pump. Manually-adjustable variable-speed (V.S.) drive, 0-50 gpm @ 100 psig discharge pressure.	MOYNO 365-CDQ-AAA Variable-speed (V.S.) drive, 0-50 gpm @ 100 psig, TEFC motor.	7.5	Existing Former 430-P-03 on Module No. 207A/B-06
P-1002	Flush System Submerged Pump	1	Submersible trash/slurry pump 200 gpm @ 50' head. Equipped with cage stand inlet with flush system submerged pump NEMA 4X Control Station.	Grindex Submersible Trash Pump, Model Salvador, 3" NPS discharge, 60 lbs. wt., TEFC motor.	2.5	New Purchase
PIP-1001	Cross-Country Transfer Piping - 2"	20	2" reinforced rubber hose in 100-ft sections HP 316SS Kamlock M&F connectors			New Purchase
PIP-1002	Vacuum-Suction Transfer Piping - 4"	8	4" suction hose in 50-ft sections Kamlock M&F connectors			New Purchase
PIP-1003	Containment Piping - 4"	10	4" collapsible fire hose in 100-ft sections M&F locking collar connectors			New Purchase
SP-1001	Sludge Suction Wand	2	4" Suction head (Hi-Vac) with suction control			New Purchase
SP-1002	Flush System Wand	2	2" NPS PVC/Rubber hose wand with manual control valve			New Purchase

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE TWO

AREA 1000: SLUDGE REMOVAL AND TRANSFER UNIT (SRTU) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
CON-1001	Oversized Waste Container	1	Covered dumpster metal container	4'W x 7.5'L x 4'H 120 ft^3 capacity		Existing
LFT-1001	Man Lift	1	Hydraulic gondola or scissor-jack type man lift with working platform large enough for two people and 1000 lbs lifting capacity. Mobile or transportable by fork lift.		10	New Purchase
FIS-1001	Sludge Transfer Flow Indicating System	1	Flow monitoring system, including: - One in-line en-masse flow-measuring element - One pipe-mounted flow transmitter - One panel-mounted flow indicator	Micromotion, 316L, 2" NPS	1 equivalent	Existing former FIT-115
MIS-1001	Sludge Transfer Mass Indicating System	1	Pond sludge TSS concentration monitoring system, including: - One in-line TSS-measuring element - One pipe-mounted transmitter - One panel-mounted TSS concentration indicator	McNab Turbidimeter, 2" NPS	1 equivalent	Existing HNUS #14-05
LCS-1001	Sludge Removal Level Control System	1	Level control system for VTS-1001 discharge hopper. System includes: - One hopper-mounted ultrasonic level-measuring element - One local level transmitter - One panel-mounted level indicator-controller with HI and LO level switches and alarms		1 equivalent	New Purchase

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE THREE

AREA 1000: SLUDGE REMOVAL AND TRANSFER UNIT (SRTU) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
CP-1001	Sludge Removal and Transfer Unit Control Panel	1	Unit-mounted NEMA 4X enclosure with face-mounted instruments and controls, front-mounted access door. Includes: - Sludge flow Indicator (gpm) - Sludge suspended solids concentration indicator (%) - Level Indicator for VTS-1001 discharge hopper - HAND-OFF-AUTO switches for VTS-1001 vacuum pump and P-1001 - V.S. controller and speed indicator for P-1001 - HI-LO level alarms for VTS-1001 discharge hopper - Running lights for electric motors - Emergency System-wide shut-down button for all equipment		3 Equivalent	New Purchase

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE FOUR

AREA 2000: SLUDGE FEED UNIT (SFU)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
D-2001 D-2002	Sludge Feed Tanks	2	Vertical, cylindrical, cone-bottomed, closed-top tank, 10' φ x 4' H cylinder x 4'-8" cone bottom (40°) with 2,700 gallon capacity. Equipped with free-standing channel bridge support for agitator. Four baffles on inside cone side walls (6" x 4') are provided to facilitate slurry suspension.			Two new tanks. One on existing Module No. 207A/B-07, and one on new module
D-2003	Process Water Tank	1	Vertical cylindrical, covered tank. 8' φ x 9' H with approximately 2,700 gallon capacity. Modified side entry port and adjusted high-level control. Side mounted heating panels and integrated temperature control system to permit modest temperature elevation (to 35-40°C).	50 Kw heating panels	70 equivalent	Existing Tank 430-S-06 on Module No. 207A/B-07 modified as required[1].
A-2001 A-2002	Sludge Feed Tank Mixers	2	Top-mounted on bridge above D-2001 and D-2002. Will need longer impeller shaft and bridge support.	Burnhams-Sharp XLG-500 mixer with Lightnin A-310 pumping impeller, 2 ft diameter, V.S. drive.	7.5 (each)	One Existing Agitator 430-A-01 Formerly mounted in tank 430-SU-01 on Module No. 207A/B-02. One new agitator.
P-2001 P-2002	Sludge Feed Pumps	2	Progressive-cavity, positive-displacement pump, V.S. drive, 50 psig, 0-40 gpm.	MOYNO 2E012G1-CDQ-HSA, TEFC motor	5 (each)	One Existing Pump 430-P-05 on existing Module No. 207A/B-07. One new pump on new module
P-2003	Process Water Pump	1	Horizontal centrifugal pump with 200 gpm capacity @ 112 psig discharge pressure.	4" X 3" Wilfley Model AG pump, TEFC motor	40	Existing Pump 430-P-06 on Module No. 207A/B-07.

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE FIVE

AREA 2000: SLUDGE FEED UNIT (SFU) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
P-2004	Flush Water Pump	1	Horizontal centrifugal pump with 150 gpm capacity @ 50 psig discharge pressure.	3" x 2" Wilfley Model AG pump, TEFC motor	20	Existing Pump 430-P-02 on Module No. 207A/B-07[1]
P-2005 P-2006	Decant Pumps	2	Self-priming horizontal centrifugal slurry pumps with 90 gpm capacity at 20' psig, 1-1/2" discharge. TEFC motor.	Teel self-priming pump Model 2P374, TEFC motor	1.5 (each)	New Purchase[1]
FCS-2001	Sludge Feed Flow Control System	1	Pond sludge flow monitoring system, including: - One in-line en-masse flow-measuring element - One pipe-mounted flow transmitter - One panel-mounted flow rate indicator with input to MBTU logic controller	Micromotion, 316L, 2" NPS	1 equivalent	Existing Former FIT-221
MCS-2001	Sludge Feed Mass Control System	1	Pond sludge TSS concentration monitoring system, including: - One in-line TSS-measuring element - One pipe-mounted transmitter - One panel-mounted TSS concentration indicator with input to MBTU logic controller	McNab Turbidimeter, 2" NPS	1 equivalent	Existing HNUS #14=05
CCS-2001	Sludge Feed Conductivity Control System	1	Pond sludge TDS concentration monitoring system, including: - One in-line TDS-measuring element - One pipe-mounted transmitter - One panel-mounted TDS concentration indicator with input to MBTU logic controller	Signet conductivity cell, Model F/05660-22, Analog analyzer, indicator.	1 equivalent	Existing HNUS #14-12

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE SIX

AREA 2000: SLUDGE FEED UNIT (SFU) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
LCS-2001 LCS-2002	Sludge Feed Level Control Systems	2	Level control systems for D-2001 and D-2002. Each system includes: - One tank-mounted ultrasonic level measuring element - One local level transmitter - One panel-mounted level indicator-controller with HI and LO level switches and alarms		1 equivalent (each)	New Purchases[1]
LCS-2003	Process Water Level Control System	1	Level control systems for D-2003. Each system includes: - One tank-mounted resistivity-type level measuring element - One local level transmitter - One panel-mounted level indicator-controller with HI and LO level switches and alarms		1 equivalent (each)	New Purchases[1]
CP-2001	Sludge Feed Unit Control Panel	1	Unit-mounted NEMA 4X enclosure with face-mounted instruments and controls, front-mounted access door. Includes: - Sludge flow indicator (gpm) - Sludge TSS concentration indicator (%) - Sludge TDS concentration indicator (%) - Level indicators for D-2001, D-2002, and D-2003 - HAND-OFF-AUTO switches for A-2001, A-2002, P-2001, P-2002, P-2003, and P-2004 - V.S. drive controls and speed indicators for A-2001, A-2002, P-2001 and P-2002 - HI-LO level alarms for D-2001, D-2002, and D-2003 - Running lights for electric motors - Emergency system-wide shut down button for all equipment		3 equivalent	New Purchase[1]

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE SEVEN

AREA 3000: TREATMENT ADDITIVES STORAGE AND FEED UNITS (ASFUs)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
SL-3001 SL-3002	Pozzolanic Reagent Storage Silos	2	Silos are vertical, cylindrical, closed-top, cone-bottomed (60°) tanks. Fill connections equipped with quick-connect fittings. Bottom discharge equipped with knife-gate valves. Live-bottom mechanisms to prevent bridging. Passive emission control system with top-mounted baghouse type filter.	12.0' φ x 24.0' SSH + 60° cone 100 cubic yards, 86 tons capacity		New Purchase or lease[1]
SL-3003	Hydrated Lime Storage Silo	1	Silo is a vertical, cylindrical, closed-top, cone-bottomed (60°) tank. Top fill connection equipped with quick-connect fittings. Bottom discharge connection equipped with knife-gate valves. Live-bottom mechanisms to prevent bridging. Passive dust emission control system with top-mounted baghouse type filter.	10.0' φ x 14.75' SSH + 60° cone 40 cubic yards, 35 tons capacity		New Purchase or lease[1]
AFS-3001 AFS-3002	Pozzolanic Reagent Additive Feed Systems	2	Systems consist of: - One V.S. rotary valve feeder - Weigh-belt for bulk reagent with 2' x 7' measurement section, scale electronics with local and remote display of rate. V.S. drive - Horizontal, rigid, V.S. screw conveyor	12" x 12" Rotary valve prefeeder with V.S. drive 2' x 7' with V.S. 0-30 tph capacity Merrick Model 455 9" φ x 20' L, carbon steel screw conveyor, V.S. drive, 0-30 tph capacity	3 (each) 0.5 (each) 5 (each)	New Purchase or lease[1]

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE EIGHT

AREA 3000: TREATMENT ADDITIVES STORAGE AND FEED UNITS (ASFUs) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
AFS-3003	Hydrated Lime Additive Feed System	1	System consists of: - One V.S. rotary valve feeder	8" x 8" Rotary valve prefeeder with V.S. drive	3	New Purchase or lease[1]
			- Weigh-belt for bulk reagent with 2' x 7' measurement section, scale electronics with local and remote display of rate. V.S. drive	2'W x 7'L with V.S. 0-30 tph capacity Merrick Model 455	0.5	
			- Elevated, rigid, V.S. cross-country screw conveyor	9"D x 40'L, 30° rise angle, carbon steel screw conveyor, V.S. drive, 0-30 tph capacity	5	
LCS-3001 LCS-3002 LCS-3003	Storage Silos Level Control Systems	3	Level control systems for SL-3001, SL-3002, and SL-3003. Each system includes: - One silo-mounted ultrasonic level-measuring element - One local level transmitter - One panel-mounted level indicator-controller with HI and LO level switches and alarms		1 equivalent (each)	New Purchase[1]

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE NINE

AREA 3000: TREATMENT ADDITIVES STORAGE AND FEED UNITS (ASFUs) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
CP-3001 CP-3002 CP-3003	Additive Feed Unit Control Panels	3	Unit-mounted NEMA 4X enclosure with face-mounted instruments and controls, front-mounted access door. Includes: - Level indicator for storage silo - HAND-OFF-AUTO switches for rotary valve feeder, weight belt conveyor, and screw conveyor - V.S. controllers and speed indicators for rotary valve feeder, weight belt conveyor and screw conveyor - HI-LO level alarms for storage silos - Running lights for electric motors - Emergency system-wide shut down button for all equipment		3 Equivalent (each)	New Purchase[1]

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE TEN

AREA 4000: MIXING/BLENDING TREATMENT UNIT (MBTU)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
MBS-4001	Mixing/Blending System	1	Twin-shaft, V.S. drive, covered pug mill with enclosed conical feed hopper. Pumping paddles, adjustable manual discharge slide-gate valve	Nominal 20 tph product rate, (0-30 tph range), 21"W x 8'L size. (Sprout-Bauer)	60	New Purchase[1]
SCN-4001	Treated Waste Scalping Screen	1	Covered vibrating scalping screen with slotted polyurethane deck and high-frequency linear drive	Sprout-Bauer 4' x 8' linear shaking screen with 2.0 mm size opening for dry screening.	3	New Purchase[1]
CV-4001	Fines Transfer Conveyor	1	V.S. screw conveyor	9"ϕ x 40'L, carbon steel screw conveyor, V.S. drive, 0-40 tph capacity	5	New Purchase[1]
CV-4002	Treated Waste Transport Conveyor	1	Flexible pocket belt conveyor. V.S. drive with cover and shrouded discharge chute.	30"W x 50'L with 4.5"H x 12"W pocket segments. Manual V.S. drive, 0-40 tph capacity. Cambelt Model CWR3045-12	5	New Purchase[1]
CV-4003	Recycle Conveyor	1	V.S. elevating screw conveyor	9"ϕ x 43'L, carbon steel screw conveyor, V.S. drive, 0-40 tph capacity	5	New Purchase[1]
JS-4001	Container Jockey System	1	Two-way jockey cable-pull to spread treated waste evenly throughout the waste container. Has electric cable winch system, rigid frame and integral tracks for guiding container with travel limit stops.	Winch by Winches, Inc., rigid frame and support base for 30 ton load.	25	New Purchase[1]
D-4001	Mixer Flush Water Tank	1	Skid-mounted tank which receives flush water and solids from mixer/blender flushing. Equipped with a vertical slurry sump pump and HI-LO level switches.	5' ϕ x 5' H C.S. tank with vertical sump pump. 575 gallon capacity.		Existing Tank[1] 430-SU-02 mounted on existing skid No. 207A/B-07

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE ELEVEN

AREA 4000: MIXING/BLENDING TREATMENT UNIT (MBTU) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
P-4001	Mixer Flush Water Pump	1	Vertical centrifugal slurry pump	3"D x 60"L vertical centrifugal slurry pump, Gallagher Model 5100, 200 gpm @ 50 psig head, TEFC motor	25	Existing Tank[1] 430-P-07 mounted on existing skid No. 207A/B-07
DCS-4001	Dust Collection System	1	System includes: - Dust collection ductwork - Dry-type baghouse - HEPA Filter - Exhaust blower system uses exhaust blower low-pressure air for back-blow of filter leafs	- 6" OA4 ridged steel duct work - Dust Vent Model 2-150 multiple-fold fabric filter collector, 37"L x 28"W x 31"H with 24" cone-bottom hopper with slide-gate valve. 8.4 ft^3 active capacity. Equipped with shaking motor and low-pressure back-blow - Dual 24" x 24" x 12" HEPA filters, 0.5 micron openings, one operating, one spare, 1000 cfm capacity - 1000 cfm exhaust blower @ 0.5 psig discharge pressure	3 10	New Purchase[1] or Lease
CON-4001	Dust Container	1	Dust holding bin with passive vent filter	Tote 42" L x 48" W x 42" H 48 ft^3 capacity		New Purchase[1]
LCS-4001	Mixer Flush Level Control System	1	Level control for D-4001. System includes: - One tank-mounted resistivity level-measuring element - One local level transmitter - One panel-mounted level indicator-controller with HI and LO level switches and alarms		1 equivalent	New Purchase[1]

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE TWELVE

AREA 4000: MIXING/BLENDING TREATMENT UNIT (MBTU) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
CP-4001	Mixing/Blending Treatment Unit Control Panel	1	Unit-mounted NEMA 4X enclosure with face-mounted instruments, controls and front-access door. Panel to include: - Feed rate (weight) indicators for all components being fed to MBS-4001. Includes: Sludge flow rate, pozzolan mix feed rate, hydrated lime, and computed free water feed rate - Logic controller output for mix control setting linked with AFS-3001, AFS-3002 and AFS-3003 with HAND-OFF-AUTO rate control settings - HAND-OFF-AUTO switch for JS-4001 - ON-OFF switches for MBS-4001, SCN-4001, CV-4001, CV-4002, CV-4003 and DCS-4001 exhaust blower and bag vibrator motor - V.S. drive controls and speed indicators for MBS-4001, CV-4001, CV-4002, and CV-4003 conveyors - Level indicator for D-4001 - HI and LO level alarms for D-4001 - Running lights for the electric motors - Emergency system-wide shutdown button for all equipment		3 Equivalent	New Purchase[1]

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE THIRTEEN

AREA 5000: TREATED WASTE STORAGE AND TRANSPORT UNIT (TSTU)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
CON-5001 to CON-5012	Treated Waste Containers	12	Roll-off type containers with removable top cover (window-shade, double-reel type), end-dump gate and bottom wheels for jockey system tracks.	Nominal 30 yd^3, standard steel roll-off container. Approximate dimensions: 6'2"H x 8'0"W x 23'0"L Will hold approximately 22 yd^3.		New Purchase

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE FOURTEEN

AREA 6000: TREATED WASTE RECYCLE UNIT (TWRU)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
VTS-6001	Treated Waste Recycle System	1	Self-contained, mobile, wet-dry type vacuum system including: - One 2,400 cfm @ 15" Hg vacuum pump with 375 to 750 lbs/min handling capacity - One 75 ft^3 60° cone-bottom hopper with rotary-valve airlock - One 5" dia. rotary valve feeder with V.S. drive, manually adjustable - Three HEPA filters on vacuum pump discharge	- Hi-Vac Model 275 mobile vacuum system - 75 ft^3 hopper - Rotolok 5" x 5" - Three 24" x 24" x 12" HEPA filters, 0.5 micron, 1000 cfm capacity each	40 5	Existing[1]
PIP-6001	Treated Waste Suction Piping	4	4" suction hose in 50-ft sections. HP 316SS Kamlock M&F connectors	4" NPS - HI-Vac Hose		New Purchase[1]
SP-6001	Treated Waste/Dust Suction Wand	1	Semi-hard rubber wand equipped with manual pinch control valve	4" NPS - HI-VAC Hose		New Purchase[1]
LIS-6001	Treated Waste Recycle Level Indicating System	1	Level indicating system for VTS-6001 discharge hopper. System includes: - One hopper-mounted ultrasonic level-measuring element - One local level transmitter - One panel-mounted level indicator-controller with HI and LO level switches and alarms		1 equivalent	New Purchase[1]

TABLE A-1
ACCELERATED POND SLUDGE PROCESSING
CONCEPTUAL DESIGN
EQUIPMENT LIST - PAGE FIFTEEN

AREA 6000: TREATED WASTE RECYCLE UNIT (TWRU) (Continued)

Item Number	Equipment Name	Number Required	Equipment Description	Equipment Size/Model, Etc.	Installed Power (HP)	Status
CP-6001	Treated Waste Recycle Unit Control Panel		Unit-mounted NEMA 4X enclosure with face-mounted instruments and controls, front-mounted access door. Includes: - V.S. controller and indicator for rotary feeder - ON-OFF switches for vacuum pump and rotary valve feeder - Running lights for electric motors - Level indicator for VTS-6001 discharge hopper - HI-LO level alarms for VTS-6001 discharge hopper - Emergency system-wide shut down button for all equipment		3 Equivalent	New Purchase

[1] Also required for Pondcrete processing.

APPENDIX B

MODELING REPORT

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
OPERABLE UNIT 4 SOLAR PONDS DISPOSAL FACILITY
WASTE ACCEPTANCE CRITERIA DEVELOPMENT

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OPERABLE UNIT 4 SOLAR PONDS DISPOSAL FACILITY
WASTE ACCEPTANCE CRITERIA DEVELOPMENT

The liquid-phase Waste Acceptance Criteria (WAC) is the chemical-specific leachate concentration generated from the waste material in an engineered disposal facility which will ensure an acceptable groundwater concentration at the point of compliance (POC) within a required protective time frame. The waste material to be placed in the disposal facility is from the Solar Evaporation Ponds (SEP)s at the Rocky Flats Environmental Technology Site (RFETS). The leachate concentrations of treated or untreated waste materials which are proposed to be placed in the disposal facility will be estimated using the Toxicity Characteristic Leaching Procedure (TCLP). The material-specific TCLP results will then be compared to the WAC value to determine whether the material is acceptable for placement in the disposal facility.

B.1.0 INTRODUCTION AND OBJECTIVES

This report presents WACs for the SEP disposal cell and a brief description of their development. The objective of the WAC development is to support the treatability study by providing a measure that can be used to determine the acceptability of either the untreated or treated waste material for placement in the disposal facility. For untreated waste material which is unacceptable to be placed in the disposal facility, the WACs will be used to determine the acceptability of the proposed mix designs to stabilize and treat the waste material. The WACs were developed for the same constituents of concern (COCs) that are to be tested for in the treatability study of Operable Unit 4 (OU4) waste materials (i.e., soil, sludge, debris, and pondcrete). The COCs are listed in Table B-1 along with the acceptable groundwater concentrations at the POC (Engineering Science/Parsons, 1995).

A computer groundwater contaminant fate and transport model for the SEPs was developed and calibrated using available site-specific data to support the WAC development. In the development of the model, previous modeling efforts conducted for the SEPs were reviewed. This task was performed so that information already available and concepts of groundwater flow could be efficiently incorporated into this modeling effort without duplicating work. The review of these previous modeling efforts is summarized in Section B.4.0. Site-specific data along with the available pertinent information from previous modeling was then used when appropriate in the development of the WAC development model. Once the model had been calibrated, it was used to determine WACs for various disposal facility designs and for a range of infiltration rates through the engineered infiltration barrier (cap). The range of infiltration rates will allow for design changes and/or changes in the assumptions of the long-term performance of the cap without the need for redeveloping the WACs.

B.2.0 CONCEPTUAL MODEL

The conceptual model of the contaminant fate and transport represents a simplified but conservative interpretation of the complex natural overburden and aquifer system under the RFETS and the movement of contaminants within it. The following paragraphs describe the groundwater flow beneath the SEPs and the simplified representation of it used in the WAC development model.

The SEPs currently consist of five ponds (207-A, 207-B [North, Central, and South], and 207-C). In the vicinity of pond 207-C, three ponds once existed but have since been removed and replaced by pond 207-C. The SEPs received process wastes (liquid and sludge) and sanitary effluent, which then evaporated from the ponds. The first ponds in this area were built in the mid-1950s. The ponds leaked and were repaired several times over their service life. It has been shown that the leakage from the ponds has adversely impacted groundwater quality beneath the SEPs (DOE 1993a). The groundwater in the vicinity of the RFETS has been grouped into upper and lower hydrostratigraphic units (UHSU and LHSU respectively). The UHSU, or "upper" aquifer, is unconfined and consists of surficial material (alluvium), weathered bedrock, and sandstone in hydraulic connection with the surficial deposits. The LHSU is a confined aquifer; however, the present understanding of the hydrogeologic relationships indicate that there are no known bedrock pathways through which groundwater contamination can directly leave the RFETS and migrate into a confined aquifer system off site (EG&G 1994). The groundwater table of the UHSU in the vicinity of the ponds is very close to the bottom elevation of SEPs. The material under the ponds consist of a relatively thin layer of alluvium on top of weathered bedrock, which in turn is on top of unweathered bedrock. Groundwater flow through the alluvium and the weathered bedrock under the ponds is generally to the north and east toward North Walnut Creek.

Conceptually, the liquids in the ponds leaked out of breaks in the pond liners into the unsaturated zone beneath the ponds. Some of the contaminants were adsorbed to the unsaturated soil as the contaminated liquids percolated to the saturated zone. When the leaks in the ponds were patched, the vertical flow of liquid through the contaminated soil was cut off so the contaminants had a tendency to remain in the unsaturated soil. In the saturated zone, some of the contaminant adsorbed to the soil and some traveled with the groundwater.

The historical loading of contaminants to the groundwater from the SEPs is very complex. The various construction techniques and timing of the construction of the SEPs, the varying contents and usage of the ponds, and the location and duration of leaks from the various ponds all contribute to a very heterogeneous contaminant loading pattern from the SEPs. This contaminant loading pattern has resulted in contaminant plumes under and around the SEPs that show a high degree of variability.

Comparison of the contaminant concentrations in the saturated zone over time with water-level measurements over time indicate that contaminant concentrations increase following rises in the water-table elevation beneath the SEPs. Figures B-1, B-2, and B-3 show plots of tritium, nitrate, and uranium-238 concentrations, respectively, in well 2886 with time. These figures also present the water-level in these wells over the same time period that the concentration measurements were made. As can be seen from the plots, following the period of high water around June 1987, the concentration for each of these constituents increased. The same effect is shown to a lesser degree following a period of high water in April 1992 for nitrate and tritium. This may have been caused by water entering soil that is generally unsaturated and washing previously adsorbed contaminants out of this zone. The smaller fluctuations in the groundwater table do not show the corresponding fluctuation in the concentrations because the portion of soil that is becoming saturated is regularly saturated so the release of constituents from the soil is more constant.

The WACs were developed for the future condition which includes the proposed disposal cell. The proposed disposal cell design incorporates a low permeability engineered cover approximately ten feet thick. The waste materials are in turn located under the engineered cover. There is no liner below the waste materials in the proposed design. The design does include a drainage layer beneath the waste to prevent the groundwater table from rising and coming in contact with the waste material. Conceptually, if the groundwater table rises, water will enter the drainage layer. This layer is designed to carry the flow laterally away before it can rise further and come in contact with the disposal cell contents. In the event that contaminants do leach out of the disposal cell (the focus of this study), the leachate will enter this drainage layer and travel laterally to the POC. In this case, if the leachate was not collected, the WACs would directly match the groundwater compliance criteria. The development of the WACs presented herein considers the time frame in which the maintenance of the disposal cell can no longer be assured. Since the design life of the disposal cell is 1000-years, it is unlikely that maintenance on the disposal facility will be continued for the entire design life. It is assumed then that the drainage layer beneath the disposal cell becomes plugged and does not function. The leachate leaving the disposal cell then migrates vertically down into the unsaturated and saturated zones beneath the disposal cell, where it travels with the groundwater.

WACs were developed for three design scenarios. The first scenario is the proposed design condition presented in the IM/IRA Decision Document (DOE, 1995a) and is the focus of the treatability study. The other two scenarios were conducted to determine the WACs under conditions where the groundwater flow under the disposal cell is cut off with shallow trenches. These two scenarios were developed during the WAC development to determine the effect of limiting the groundwater flow beneath the disposal cell. In scenario 2, shallow trenches would be constructed around the disposal cell to limit the fluctuation of the water table under the disposal cell. In scenario 3 the trenches are constructed deeper to the bedrock surface to cut off more groundwater flow under the disposal cell.

B.3.0 MODELING TOOLS

The WACs were determined using a computer groundwater contaminant fate and transport model. This model is implemented on the spreadsheet software Excel 4.0 and Crystal Ball 3.0 and is called ECTran (which stands for Excel-Crystal Ball Transport [Chiou 1993, DOE 1993b]). Based on a conceptual understanding of the site, the ECTran model of the SEPs was first calibrated to simulate the existing contaminant plumes, process which enabled the estimation and further refinement of flow and chemical mobility parameters. The following paragraph discusses how the conceptual groundwater flow and contaminant fate and transport at the SEPs discussed above was modeled with ECTran.

The conceptual model of the groundwater flow under the SEPs includes two layers, an unsaturated zone and a saturated zone. Based on the average high water-table elevation, a typical, conservative (thin) thickness of the unsaturated zone was estimated to be 3 feet and the saturated thickness above the bedrock was estimated to be 5 feet. For the WAC development of this modeling task, the ECTran simulation begins at the bottom of the disposal cell (i.e., leachate concentrations exiting the disposal cell are input into the ECTran simulation). The ECTran model uses constant layer thicknesses. The underlying bedrock and the flow through it were not simulated for most of the WAC development scenarios in the modeling since the flow through the bedrock of the UHSU is much slower than the alluvium (DOE 1993a). For the scenarios in which flow through the alluvium is not controlled, contaminants that leak out of the disposal facility will reach the POC quicker in the alluvium (than in the bedrock) so the model-predicted concentrations in the saturated alluvium were used to determine the WAC values. For the scenario in which the flow through the alluvium is controlled, the predicted concentration in the bedrock at the POC is used to develop the WACs. Additional constant water flow through the unsaturated zone was added in the model to simulate the washing effect on the unsaturated zone by the fluctuation of the groundwater elevation. The amount of this additional flow through the unsaturated zone was estimated during the model calibration.

B.4.0 REVIEW OF PREVIOUS MODELING EFFORT AT THE SEPS

In addition to the ECTran model set up to develop WACs and described in this appendix, three other modeling efforts have been under taken specifically for the SEPs. The three other models which have been or are being applied to the SEPs are as follows: infiltration estimation through the proposed low permeability cover with the Hydrologic Evaluation of Landfill Performance (HELP) model (Schroeder et al, 1994, 1988), contaminant leaching from the disposal cells through the unsaturated zone beneath the disposal cell with the VLEACH model (as described in the IM/IRA Document [DOE, 1995]), and in an ongoing task, the VS2DT model (USGS, 1993) is being set up to provide a more detailed contaminant flow and transport analysis describing the leaching of the contaminated materials out of the disposal cells and the subsequent transport of the contaminants in the unsaturated and saturated zones. Results of the HELP model and the VLEACH model are presented in the IM/IRA Document (DOE, 1995a). A description of the VS2DT model is presented in the IM/IRA document and preliminary results of this ongoing modeling effort have been provided to HNUS to review. The following paragraphs will summarizes the modeling effort of each of these three tasks. A discussion will then be presented which describes the purposes of the WAC development in relationship to these other modeling efforts at the SEPs.

B.4.1 HELP Model Application

The annual infiltration through the proposed engineered cover of the disposal cell was estimated using version 2.05 of the HELP model. The HELP model simulated flow through the cover system using available site-specific and simulated climatological data. Six modeling scenarios are presented in the IM/IRA document. The modeling scenarios range from a normal condition to a condition assuming a 300 percent increase in precipitation due to possible climatic changes over the 1000-year design life of the disposal cell. The infiltration under normal conditions was estimated as 0.0068 inches of infiltration per year. For the 300 percent increase in precipitation case, the infiltration increased to 0.0075 inches of infiltration per year. Discussed in Section B.5.1, the current amount of infiltration around the SEPs was estimated to be about 1 inch of infiltration per year. These results indicate that the engineered cover as designed will significantly decrease the amount of infiltration which reaches the waste material even under a conservative assumption of substantial changes in the climatic conditions over the 1000-year design life of the facility.

B.4.2 VLEACH Model Application

The VLEACH model is a one-dimensional vadose zone leaching model developed for the EPA. The modeling at the SEPs was conducted using version 1.02 of this model. The model is capable of simulating the movement of contaminants in the vertical direction through an unsaturated zone. The VLEACH model used for the SEPs and described in the IM/IRA document modeled a 27 foot thick column representing the disposal cell. This 27 foot column was divided into 27 one foot thick finite difference cells. Each of the cells in the VLEACH model must be described by the same physical parameters but can contain varying contaminant concentrations. The top ten feet of the column represented the engineered cover which was assumed to be clean, the next fourteen feet represented the waste materials, and the final three feet represented the drainage layer under the landfill (also assumed to be clean).

The VLEACH model simulated the leaching of contaminants from the disposal cell contents down to the drainage layer. The concentration of the disposal cell contents was estimated based on a volumetric average of the proposed contents of the disposal cell without treatment. The leaching of seven COCs were modeled using VLEACH assuming literature values for the soil / water partitioning coefficient, K_d. Four model scenarios were run using infiltration rates through the disposal cell estimated with the HELP model. One scenario assumed no action at the SEPs, and three scenarios were run assuming the proposed engineered cover was in place and varying climatic changes (normal, 300 percent increase in precipitation, and a projected 100 year storm event). The maximum leachate concentration was then converted to a depth averaged concentration in the groundwater beneath the disposal cell. This concentration was then compared to the compliance criteria. The no action scenario produced contaminant concentrations above the compliance criteria. All of the capping scenarios estimated contaminant concentrations below the compliance criteria.

B.4.3 VS2DT Model Application

The VS2DT model of the SEPs is currently under development. The VS2DT model is intended to be used primarily as a design tool during the Title II design. The VS2DT (Version 2.0) is a numerical two-dimensional multi-layer, variably saturated contaminant transport computer model developed by the U.S. Geological Survey (Lappala, et al., 1993, Healy 1990). The VS2DT model will allow a more detailed analysis of the leaching of contaminants from the disposal cell contents. The VS2DT results are expected to confirm or validate the VLEACH model results (DOE, 1995a). Advantages of the VS2DT code over the VLEACH model is the ability to simulate the lateral flow of contaminants in the drainage layer under the disposal cell, and the VS2DT model will allow different physical parameters to be assigned to various cells in the model which was not possible in the VLEACH model. The VS2DT model will also allow for a varying distribution of contaminant parameters in the horizontal plane. This ability will allow a more detailed analysis of the leaching of contaminants from the waste disposal cell.

Preliminary model runs have been made for four COCs with the VS2DT model. (ES/Parsons 1994) The preliminary runs consisted of a two-dimensional model grid of a cross section through the proposed disposal cell. The VS2DT model grid includes the contaminated material, the drainage layers under the disposal cell contents, the variably saturated underlying soil, and an assumed impervious bedrock layer beneath the soil. The K_d values used in the preliminary VS2DT runs were based on literature values. In the description of the preliminary results, the need for using site specific partitioning and physical soil parameters was expressed. At the present time the VS2DT modeling is awaiting completion of lab tests conducted to estimate these site specific parameters.

B.4.4 Comparison of Modeling Applications

Each of the contaminant transport codes, VLEACH, VS2DT, and the ECTran (described in Section B.3.0) use the HELP model predicted average infiltration amounts thought the disposal cell. The WAC development incorporates a very conservative approach by determining the maximum leachate concentration leaving the disposal cell which will result in an acceptable groundwater concentration if that leachate concentration was being uniformly released under the entire disposal cell. In this way, no matter where the waste is placed within the disposal cell as long as it does not produce a leachate concentration higher than the WAC, the groundwater concentration at the point of compliance will not be exceeded. In this way the ECTran model objective is to create a bound on the contaminant concentrations in the groundwater (i.e., WAC only attempts to ensure that the groundwater concentration is below a certain value). The VS2DT model in contrast when completed, will attempt to predict the groundwater concentration knowing the types, location within the disposal cell, and quantity of each of the materials being placed in the engineered cover. The VS2DT model will be used to confirm the other modeling which was completed for the SEPs. The WACs were developed with the ECTran model so that conservative criteria could be developed in a timely manner and used for the treatability study of the material to be placed in the disposal cell.

B.5.0 ECTran MODEL CALIBRATION

The ECTran model calibration is used to ensure that the computer model set up in accordance with the conceptual understanding of the site is accurately or conservatively simulating the transport of contaminants. The calibration is completed by refining estimations of model input parameters (e.g., flow parameters and chemical mobilities). Once the model has been calibrated, it was used to determine the WACs. During the model calibration, the past loading of contaminants are simulated and the input parameters adjusted until the predicted groundwater contaminant concentrations match the groundwater sample results. The computer model of the SEPs is a simplified representation of the subsurface movement of contaminants. Due to the heterogeneous nature of the contaminant loading and the corresponding variation of the contaminant concentrations in the groundwater, the simplified, modeled representation of the contaminant transport only attempts to yield an acceptable prediction of the typical measured groundwater data and is not intended to match every data point.

The calibration allowed the estimation of parameters which could not be or had not been measured and therefore were unavailable for use in the current modeling. The model calibration resulted in estimates of model parameters such as layer- and COC-specific soil/water partitioning coefficients (K_ds), infiltration rate, and lateral flow rates in both the unsaturated and saturated zones.

Calibration data were available from: previous modeling efforts for the SEPs, groundwater analytical data, lysimeter analytical results in the unsaturated zone beneath and around the SEPs, soil analytical results from samples taken from the lysimeter bore holes, and characterization of the pond contents for two periods (1984-1988, and 1991).

Groundwater analytical data were available for 46 wells in the vicinity of the SEPs. Only the wells which were screened in the UHSU were considered in the calibration. The wells were grouped into three categories: upgradient, under-source, and downgradient wells. Wells which were cross gradient to the average high water-level contours were not used in the calibration. The model was then calibrated to predict concentrations which were representative of the measure groundwater concentrations. Table B-2 lists the wells used in the calibration. The well data span the time frame from 1987 to the present; however, most of the data are more recent.

B.5.1 Hydraulic Parameters

Simulating the past loading of contaminants requires knowing the amount of water leaking from the ponds to the groundwater. This was estimated by calculating the groundwater flow rate upgradient and downgradient of the SEPs and performing a mass balance to determine how much water entered the system. The water entering the system would represent the amount of water infiltrating into the pervious ground surface surrounding the ponds and the amount of water leaking from the bottom of the ponds. It was assumed that the water infiltrating vertically to the bedrock was negligible for this estimate of the infiltration rate, since the groundwater velocity in the bedrock has been estimated to be much less than the alluvium, which would indicate a lower hydraulic conductivity. Calculation of flow velocities and gradients were based on the average high water-table elevations. The hydraulic conductivities were based on the values presented in a previous modeling effort at the SEPs (i.e., preliminary VS2DT runs).

The model was first calibrated using tritium because the mobility of tritium is very close to that of water (DOE, 1995a) so that a good estimate of the soil/water partitioning coefficient (K_d) (e.g., very close to zero) can be made. Since tritium's mobility is already known, it was used to estimate or refine the flow parameters in the model, such as the infiltration rate, the flow used to simulate the fluctuating groundwater table in the unsaturated zone, and the flow parameters in the saturated zone. Some of the tritium concentrations in the groundwater were higher than the available characterization of the contents of the ponds. The source of contamination must have been higher at some time prior to the characterization available from 1984-1988 and 1991 to cause these higher groundwater concentrations. Because the source loading must have been higher than the characterization concentrations of the ponds, the source concentration for tritium was then calibrated along with the flow parameters. The length of source loading was taken as 32 years for tritium (the time that pond 207-A was put into operation in 1956 until the sludges were cleaned out of this pond in 1988). For the model calibration, ponds 207-A and the 207-B ponds were simulated using a single source area because of the proximity of the ponds. The groundwater flow from pond 207-C appears to travel almost directly north rather than north and east for the other ponds, therefore, 207-C was not included in the calibration source area (See Figure B-4). Figure B-4 is a plot of the mean seasonal high groundwater elevations with the source area used in the ECTran model for calibration superimposed on it. Figure B-4 is reproduced from the OU4 IM/IRA Decision Document (DOE, 1995a). Figure B-5 presents the conceptual model used for calibration.

Tritium was calibrated to three points in the flow system below the SEPs, in the unsaturated zone under the source, the saturated zone under the source, and the saturated zone downgradient of the source area. Lysimeter 43193 upper cup results were used as the calibration target for the unsaturated zone. Tritium sample results from the under source wells (both alluvium and bedrock) were used for the saturated zone, and results from wells P209889 and P209589 were used for the downgradient targets. Both of these wells are screened in the bedrock but were still used in the calibration of tritium, since no downgradient wells screened in the alluvium were available for calibration. Plots of the predicted and measured groundwater concentrations for tritium for each of these points are shown in Figures B-6 through B-8. As can be seen in Figures B-6 through B-8, the measured concentration data fluctuates. The model calibration is intended to predict typical concentrations and so the predicted concentrations do not fluctuate to the same degree as the measured data.

Figure B-7 includes the upgradient well concentrations in addition to the under-source wells for reference. As can be seen from the plots, the concentration of tritium decreases rapidly under the source as the source loading decreases. This indicates that the tritium is being "washed" out from underneath the source. The downgradient wells do not show this same effect as rapidly because the washing effect is delayed by the groundwater travel time to the downgradient wells. The predicted downgradient concentration matches the data from well P209889 much better then well P209589. Well P209589 tritium concentration is higher than well P209889. This may be the result of a quicker washing effect at well P209889, which indicates a higher flow of water around this well. Calibrating to this well should result in more conservative flow parameters to be used in the development of the WACs. The calibrated hydraulic flow parameters are shown in Table B-3.

B.5.2 COC Mobility Parameters

The fate and transport calibration of the COCs used the hydraulic parameters defined from the calibration of tritium. The COCs were primarily calibrated to concentrations in the under-source wells, since the POC for the WAC development is essentially under the source.

The initial values of the mobility parameters (K_ds) were estimated two ways and then refined by the model calibration. The first estimate of the K_d values was made by reviewing literature values and values used in previous modeling at the SEPS for each of the COCs (see section B.4.0). The second method calculated K_d values based on liquid concentrations of pore water in the vadose zone from the lysimeter data and soil concentration data from soil samples taken in the same location and depths as the lysimeter cups. It was assumed that the liquid and soil concentrations were at equilibrium. Based on this assumption, a K_d value was then estimated from this data by dividing the solid concentration by the liquid concentration after subtracting out the background concentrations. Any data pairs in which one or both of the solid and liquid concentrations were either nondetect or below background were not used in the calculation of K_d. Positive data for both solid and liquid samples were available to calculate K_d values for cadmium, uranium, and radium-226. The geometric mean of the chemical-specific K_d values calculated with the lysimeter data was used as the initial values in the calibration.

The K_d values were then refined by the model calibration. By definition, the K_d value represents the soil water partitioning coefficient, which is a measure of a chemical's affinity to adsorb to soil from the liquid phase and is therefor a measure of the chemical's mobility through its interaction of adsorption and desorption to soil. When a chemical is calibrated to groundwater data in a model which uses only the K_d value to simulate chemical mobility, the K_d value no longer only accounts for the adsorption and desorption of the chemical to the soil but also other mechanisms which are affecting the mobility of the chemical such as colloidal transport. The calibrated K_d values can then be thought of as a lumped mobility parameter accounting for the various mobility mechanisms which are occurring between the source and the measurement point of the groundwater concentration. It would not be unexpected then that the K_d values determined through calibration could be lower than literature values determined through tests which only considered adsorption and desorption.

The concentration of the liquids in the SEPs was assumed to be the source-loading concentration to the groundwater. The concentration of the contents of the SEPs were only available for two time periods; 1984-1988 and 1991. Prior to this, the concentration of the source loading to the groundwater in the model was assumed. In most cases of the calibrations, the source loading prior to 1984 was assumed to be the same as the source loading from 1984 to 1988. The source loadings used in the model were taken from the range of measured concentration data in the 207-A and the 207-B ponds. All of the calibrations of the COCs then used a two-step loading to the groundwater; the first step from years 1956 to 1988 (32 years) and the second step from 1988 on. The characterization of the SEPs in 1984 to 1988 was used for the first loading step and the characterization from 1991 was used for the second loading step.

Based on the amount of information available and the relationship of the various data available to the calibration, the calibration of the COCs can be grouped in to several categories that contain different levels of confidence in the calibration results. Most of the COC's source-loading concentrations were available for the calibration, and an ample number of groundwater sample results under the source were also available. The following are exceptions. No source-loading data was available for radium-226. The source loading was calibrated using the K_d values calculated with the lysimeter data. This calibration was conducted primarily to determine whether if it was possible for the model to predict concentrations in the groundwater similar to the measured concentrations using the calculated K_d value. The calibration of arsenic is similar in that the available source-loading matched the measured concentration under the source. The concentration of the source-loading must have been higher than the concentration under the source at sometime during the operation of the SEPs. The source concentration was then also assumed for arsenic. Only total cesium source data were available for the SEPs. It was assumed that the mobility of total cesium is similar to the cesium isotopes and could be used for cesium-134 and -137. In addition, only two sample results were available for total cesium under the source to be matched to the predicted concentration during the calibration. Due to the limited data for radium, cesium, and arsenic, the calibrated mobility values for these COC should be viewed as more uncertain that the other COCs. Very few positive detections of the organic COCs exist in the vicinity of the SEPs. Because of the lack of positive detections, calibration of the organic COCs could not be performed for these chemicals. Literature values of the K_d values were used in developing the WACs for these chemicals.

Table B-4 lists the COC-specific K_d values determined during the calibration, the literature values, and calculated K_d values from the lysimeter data. The mobility of all of the uranium isotopes was assumed to be the same so only U-238 was calibrated. For comparison purposes, Table B-5 lists K_d values used for radionuclides at other DOE facilities. The K_d values used in this study are generally within the lower range of values used at other DOE facilities. None of the K_d values used in this study are higher than this range of values and two K_ds are lower. Cesium and Plutonium K_d values for the saturated zone are lower than K_d

values reported from these other sites. This comparison shows that the K_d values used in this study are generally conservative compared to the K_d values used at the other DOE sites listed. Table B-6 lists the K_d values used for the organic COCs. The same K_d values were used for both the saturated and unsaturated zones. Figures B-9 through B-19 present plots of the calibration results under the source for each of the COCs.

B.6.0 WASTE ACCEPTANCE CRITERIA

As was discussed previously, the WAC is the leachate concentration from the waste that will not exceed the acceptable groundwater criteria at the point of compliance if the leachate percolates out of the disposal facility. The WACs were calculated for three design scenarios and a range of infiltration rates through the cap for each scenario. The range of infiltration rates will allow for the changes in the design of the cap and/or changes in the assumptions of the long-term performance of the cap. This range is much wider than those used in the previous modeling efforts (see section B.4.0) since they did not consider the potential failure of the engineered cover.

Figures B-20 through B-22 provide drawings of the conceptual models of Scenarios 1, 2, and 3, respectively, for reference during the following discussion. The first scenario is the proposed design condition presented in the IM/IRA Decision Document (DOE, 1995a) and is the scenario used to develop the WACs that the treatability study results are compared to. The other two scenarios were developed during the WAC development to determine the effect of limiting the groundwater flow beneath the disposal cell with shallow trenches and reflect potential improvements to the proposed design. Each of the scenarios is described in greater detail in the following subsections.

The radiological and environmental degradation rates of each of the COCs where taken into account when developing the WACs. The half-lives for the radionuclides are shown in Table B-4 (inorganic COCs were conservatively assumed to not degrade) . The half-lives for the organics are shown in Table B-6. As can be seen from Table B-6, the half-lives of the organic COCs are all relatively short. The source leachate loading (WAC) for the radionuclide and the inorganic COCs were assumed to be constant (time invariant) over the entire 1000 year time frame. This is a conservative assumption since the amount of contaminant leaching from the disposal cell is limited by the amount of contaminant originally in the disposal cell. Since the half-lives of the organics are relativity short, the assumption of a constant loading may be too conservative (e.g., the organic COCs may nearly completely degrade during the 1000-year modeling time frame). A depleting source modeling approach was then used for the organic COCs. The depleting source was characterized by a 14 foot thick layer of waste (matching the VLEACH waste layer, see section B.4.0) with an assumed K_d equal to the K_ds used in the saturated and unsaturated zones. The WAC for the organic

COCs was the initial waste concentration converted to a liquid phase leachate concentration with the K_d value. The development of the WACs for each of the three modeling scenarios are discussed in the following subsections.

B.6.1 Scenario 1 (Currently Proposed Design)

Scenario 1 considers the placement of the engineered cover over the waste materials, but no groundwater cut off trenches to limit the flow of groundwater beneath the disposal cell. This scenario is conceptually similar to the current hydrologic conditions except that the infiltration through the waste material is reduced due to the engineered cover. Figures B-5 and B-20 present drawings of the conceptual models of the scenarios used for calibration and Scenario 1 respectively. The range of infiltration rates for which the WACs were developed will allow for conservative assumptions concerning the long-term performance of the cap (i.e., what would the WAC be if the impermeable layer fails after a certain number of years). The WACs were determined for a range of infiltration rates between 0.0068 to 2.5 inches per year. The estimated initial infiltration through the cap under normal conditions is 0.0068 inches per year (DOE, 1995a).
The source-area size used in the development of the WAC was based on the footprint size of the disposal facility. The POC for all of the scenarios is groundwater under the edge of the disposal facility. The ECTran model calculates an average concentration in the saturated zone beneath the source area. This average concentration was compared to the acceptable groundwater concentration in developing the WACs. The initial source leachate concentration in the model is iteratively adjusted until the modeled maximum groundwater concentration in 1000 years matches the water criteria. Figures B-23 through B-37 present the WACs for each of the COCs. These figures contain plots of the WAC values for each of the three design scenarios, which were modeled for comparison purposes.

The combination of relatively short half-lives, slow flow velocities, and high K_d values resulted in the contaminant plumes from all of the organic COCs, except arochlor-1254 , from reaching the POC. Theoretically this would result in a pure product concentration for the WACs so plots are not presented for these COCs. The half-live values for arochlor-1254 was not available from literature so no degradation of this organic was assumed. This resulted in the WAC values for arochlor-1254 being less than a pure product concentration. The WAC results for arochlor ar presented in Figure B-37.

B.6.2 Scenario 2 (Potential Improvements to the Proposed Design)

Scenario 2 is similar to Scenario 1 except that shallow trenches are dug around the waste disposal facility to limit the fluctuation of the groundwater table and shallow barrier walls are constructed around the waste disposal facility. This was modeled by removing the additional flow in the unsaturated zone determined during the hydraulic calibration. Figure B-21 presents the conceptual model of Scenario 2. The other assumptions and ranges of input values are the same as Scenario 1. The same iteration process that was used in Scenario 1 is used to determine the acceptable source leachate concentration for Scenario 2. Figures B-23 through B-37 present plots of the WAC for each of the COCs which were less than a pure product concentration.

B.6.3 Scenario 3 (Potential Improvements to the Proposed Design)

Scenario 3 is similar to Scenario 2 except that the trenches around the waste disposal cell are deepened to the bedrock surface and barrier walls are constructed around the waste disposal facility. This is intended to cut off the flow in the surficial materials from migrating under the waste disposal cell. Conceptually the only movement of water under the waste disposal facility is driven by the infiltration through the cap. Also the two overburden layers in the model are both assumed to be unsaturated in this scenario. However, it is assumed that the water infiltrating through these layers flows out radially from the waste disposal facility through the underlying bedrock layer. Looking at the cell in cross section half, of the flow would flow in one direction and the other half in the other direction. The distance that the average plume concentration would need to transverse and discharge into the cutoff trench would be one quarter of the width of the disposal cell. This distance was then used to calculate the travel distance of the average plume concentration through the bedrock to the edge of the disposal facility (the POC). Figure B-22 presents the conceptual model of Scenario 3.

Figures B-23 through B-35 present the plots of the WAC for each of the COCs which were less than a pure product concentration. The WAC for some of the COCs for Scenario 3 are not presented because the combination of the slow flow velocity in the bedrock and the relatively high K_d values result in the contaminant plume not reaching the POC within the 1000 year time frame. This is similar to the organic COC case, therefore, like the organic COCs, WAC plots were not included on the figures.

B.6.4 Summary of WAC Results

The WACs developed in this study allow for many combinations of design scenarios and assumed representative infiltration rates through the disposal facility. For comparison between the WAC and the TCLP leachate results of the treated and untreated waste materials, a specific scenario and infiltration rate must be chosen. Since the current disposal facility design matches Scenario 1, this scenario is recommended to be used for comparison. The WACs for Scenario 1 are generally lower than the other two scenarios evaluated. The infiltration rate of 1 inch per year was estimated as the current infiltration rate through the SEPs area (see Section 4.1). Using this infiltration rate for the WACs will provide an additional factor of safety and could account for potential degradation of the effectiveness of the cap. The actual infiltration through the cap will likely be much less (0.0068 inches per year predicted using the HELP model, DOE 1995), therefor the WACs used are conservative. Table B-6 lists the WACs for Scenario 1 and two infiltration rates through the disposal cell; 0.0068 and 1 inch per year. Waste treatment based on the lower WACs developed using a higher infiltration rate will provide an additional safety factor for the long-term protection of the groundwater.

B.7.0 SENSITIVITY ANALYSES

Sensitivity analyses were conducted to help describe the uncertainty of the WACs and the relative sensitivity of the WACs to certain model parameters. Deterministic and probabilistic sensitivity analyses were performed to determine the conservativeness of the WAC model. In both the sensitivity analyses a base simulation was chosen with which the sensitivity runs were compared. The deterministic analysis involved varying three input parameters one at a time to see the effect on the WAC values. The probabilistic sensitivity analysis used a Monte Carlo simulation and varied the same three input parameters as were varied in the deterministic analysis. The Monte Carlo simulation allowed the three input variables to be varied at the same time to determine the combined sensitivity effects. The Monte Carlo simulation was able to quantify the conservativeness of the WAC development by analyzing several cases assuming the potential failure of the impermeable liner in the engineered cover. The entire disposal cell is designed to last for 1000 years, however, this probabilistic analysis allows the estimation of the conservativeness of the WACs assuming that sometime in the next 1000 years an unforeseen event occurs which causes the impermeable layer to degrade. The time when this degradation (changing the infiltration rate) begins was one of the input parameters varied in the Monte Carlo simulation.

B.7.1 <u>Ranges of Input Parameter Values</u>

The three input parameters varied in the sensitivity analyses were, the K_d values, the infiltration rate (the time when the infiltration rate starts to change in the Monte Carlo simulation), and the additional flow in the unsaturated zone used to simulate the fluctuation of the groundwater table beneath the SEPs. The required input for the sensitivity analyses is different for the deterministic and probabilistic approaches. For the deterministic sensitivity analysis, the range of values for each of the input parameters to be varied is required. For the probabilistic analysis, parameters to define the statistical distribution (i.e., type of distribution[normal, lognormal, uniform, etc.], the mean, and the standard deviation) of the input parameters to be varied are required. The base simulation used to compare the sensitivity results used a source loading based on the WAC for uranium-238 and 1 inch of infiltration per year (177 pCi/L). The selection of the ranges of input values to be varied and the base simulation are described in the following paragraphs.

Soil/Water Partitioning Coefficient, K_d

Uranium was chosen from the COCs to be used in this sensitivity analysis and base simulation because it had the greatest number of lysimeter pore water/soil concentrations pairs used to estimate the K_d values. The calculated K_d pairs were used to determine the distribution of the K_d values. Eight pairs were available for uranium 233/234 and 7 pairs were available for uranium-238. It is assumed that all the uranium isotopes exhibit similar mobility characteristics so both the uranium-233/234 and uranium-238 can be used to estimate the distribution of the uranium K_d value. The 15 uranium K_d values correlated well to a lognormal distribution. A lognormal distribution was then assumed for the K_d values in the saturated and unsaturated zones with the mean of the distribution set at the K_d values determined during the model calibration. The standard deviation was assumed to be twice the mean value of the distribution. These statistical parameters were then used in the Monte Carlo simulation. The mean K_d value plus and minus the standard deviation was used as the range for the deterministic sensitivity analysis.

Additional Flow in the Unsaturated Zone

The additional flow in the unsaturated zone was assumed to be uniformly distributed with a mean value matching the flow rate determined in the model calibration (3460 l/day). The maximum flow rate for the uniform distribution (5460 l/day) was determined by calculating the maximum flow in the unsaturated zone assuming the entire unsaturated zone was saturated and assuming the same groundwater velocity used in the saturated zone. The maximum flow is 1820 l/day higher than the mean. The minimum flow rate for the uniform distribution was estimated as the mean minus 1820 l/day which is also 1820 l/day. These ranges of flow were used in both the probabilistic and deterministic sensitivity analyses.

Infiltration Rate Through the Engineered Cover

The engineered cover is designed to function without losing its integrity for 1000 years. The sensitivity simulations allowed the estimation of the effectiveness of the WACs should some unforeseen events or mechanisms occur which would cause the impervious layer to degrade within 1000 years. The first step in this process was to determine the infiltration rates through engineered cover assuming a range of different hydraulic conductivities for the impervious liner which would simulate the liner under various degrees of degradation. This range of infiltration rates were used in the deterministic sensitivity analysis. The smallest hydraulic conductivity in the range equaled the hydraulic conductivity (1×10^{-9} cm/s) assumed for the cap in HELP modeling completed for the IM/IRA Decision Document. The highest conductivity was assumed to equal the that of the soil cover of the top layer of the landfill (1×10^{-1} cm/s).

In January of 1995, a new version of HELP (Version 3.03 dated December 31, 1994) was distributed. To determine the infiltration through the cap for this sensitivity analysis the most recent version of HELP was used. The same inputs used in the HELP runs presented (based on version 2.05) in the IM/IRA Decision Document were used as inputs to the version 3 HELP model. Some changes have been made in the HELP model between versions 2.05 and 3.03 (e.g., a different evapotranspiration routine is now used) so that it was not unexpected that the results of the models differed somewhat. The infiltration under normal conditions reported in the IM/IRA Decision document using HELP version 2.05 was 0.0068 inches per year, the output using the same inputs and version 3.03 of the HELP model was 0.01 inches per year. All other infiltration rates discussed in this section were determined using version 3.03 of the HELP model. The infiltration rate through the cap became fairly constant around 2.1 inches of infiltration per year at a hydraulic conductivity greater than 1×10^{-4} cm/s. The range of infiltration rates used in the sensitivity analyses were 0.01 to 2.1 inches of infiltration per year. The pattern of infiltration and timing used in the Monte Carlo simulation are described in Section B.7.3.

B.7.2 <u>Deterministic Sensitivity Analysis</u>

The range of the input variables used in the deterministic sensitivity analysis are presented in Table B-8, The rational for these variable and the ranges was discussed in the previous subsection. In this deterministic sensitivity analysis, only one variable is changed at a time; all the other input variables are held constant. The sensitivity analysis changed the input parameters in the base run (the WAC simulation for uranium-238 and one inch of infiltration described in the previous section). Figures B-38 and B-39 present plots of the sensitivity of the WAC value to the unsaturated and saturated zone K_d values, respectively. As can be seen from the plots the WAC values are sensitive to the K_d values with the WAC values increasing with the K_d values. Figure B-40 shows that the WACs are also sensitive to the infiltration rate, however, in an opposite effect as the K_d values (i.e., as the infiltration rate increases, the WAC values decreases). Two sensitivity runs were made for the additional flow in the unsaturated zone. Depending on the infiltration rate, this parameter had opposite effects on the WAC value (See Figures B-41 and B-42). Under low infiltration rates, additional flow in the unsaturated zone tends to wash contaminants out of the soil, raising the groundwater concentration and therefore lowering the WACs. As can be seen from Figure B-41 as the additional flow in the unsaturated zone increases, the WACs decreases. Under high infiltration rates, enough flow (from infiltration) is available to carry the contaminant to the groundwater so additional flow in the unsaturated zone has a tendency to dilute the groundwater concentration and increase the WAC. Figure B-42 shows that, under higher infiltration rates, as the flow in the unsaturated zone increases the WACs also increase. The deterministic sensitivity analysis shows that the WACs are fairly sensitive to the three parameters tested.

B.7.3 Probabilistic Sensitivity Analysis

The Crystal ball portion of the ECTran model (see Section B.3.0) allows Monte Carlo simulations to be performed on several of the input parameters simultaneously to ascertain the combined effects of varying these input parameters. For each of the parameters varied in the Monte Carlo simulations, a statistical distribution must be assumed. Depending on the type of distribution other statistical parameters are also required such as the mean and the standard deviation. This sensitivity simulation used the constant WAC leachate concentration for uranium-238 considering design Scenario 1 and 1 inch per year ot infiltration. The results of the simulation predict the likelihood that the compliance criteria at the POC will not be exceeded based on the WAC described above. Three input parameters were allowed to vary in the Monte Carlo simulation, and were briefly described in Section B.7.1 and are the same parameters used in the deterministic sensitivity analysis. The infiltration rate is changed in the probabilistic simulation, however, it varies according to a set pattern to simulate the degradation of the engineered cover. The time when this degradation begins is parameter described by a probability distribution in the Monte Carlo simulation.

The degradation of the liner was simulated in the sensitivity analysis with a set infiltration pattern that increased with time. It was assumed that the infiltration would take 800 years to increase linearly from the point (in time) of the beginning of the degradation and 0.01 inches of infiltration per year to an infiltration rate of 2.1 inches per year.

Four Monte Carlo cases were run. In all cases, all three of the input parameters are varied at the same time according to their respective probability distributions. One-thousand simulations were run for each case. The first case assumed that the degradation begins according to a normal distribution with a mean of 500 years and a standard deviation of 150 years. The second case assumed the same distribution for the time of initiation of degradation except the mean was 700 years. The third case had a mean of 800 years and the final case assumed that the impervious liner did not degrade in 1000 years. Table B-9 presents the input parameters and the results from the probabilistic sensitivity analysis. Figures B-43, 44, and 45 present the infiltration patterns assumed for cases 1,2, and 3, respectively. Figure B-46 presents a typical output report from the Monte Carlo simulation. The output presented is for case 1.

The compliance criteria at the POC for uranium-238 is 51.6 pCi/L. The sensitivity results show that based on the assumed degradation pattern of the impervious liner that if the liner began to degrade with a mean time of 500 years, the chance that the concentration at the point of compliance within 1000 years will not be exceeded is 65 percent. It should be noted here again that the liner is designed to last for 1000 years and these sensitivity analyses only represent "what if" scenarios in order to demonstrate the additional safety factor provided by the conservative WAC. As can be seen in Table B-9, for case 4 when the infiltration rate is not varied, the chance the contaminant concentration at the POC is below the compliance criteria is 100 percent. Also it can be seen that within 200 years the contaminant concentration is always below the compliance criteria. These simulations show that even if the liner begins to degrade during the assumed time frames and using a WAC based on one inch of infiltration a year, the WAC are still protective of groundwater the with high certainty within 1000 years and are always protective(based on the modeled cases) during the first two hundred years.

B.8.0 REFERENCES

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TABLE B-1

CONSTITUENTS OF CONCERN
AND GROUNDWATER CRITERIA
AT THE POINT OF COMPLIANCE[1]
ROCKY FLATS, COLORADO

Constituents of Concern	Acceptable Groundwater Criteria	Unit
Americium-241	2.11	pCi/L
Cesium-134	81.3[2]	pCi/l
Cesium-137	119[2]	pCi/L
Plutonium-239/240	0.207	pCi/L
Radium-226	0.63	pCi/L
Uranium-233/234	74.22	pCi/L
Uranium-235	2.98	pCi/L
Uranium-238	51.6	pCi/L
Arochlor-1254	1	ug/L
Arsenic	50	ug/L
Benzo(a)anthracene	1	ug/L
Benzo(b)fluoranthene	1	ug/L
Benzo(a)pyrene	1	ug/L
Benzo(g,h,i)perylene	1	ug/L
Benzo(k)fluoranthene	1	ug/L
Beryllium	5	ug/L
Bis-(2-ethylhexyl)phthalate	6.07	ug/L
Cadmium	18.2	ug/L
Chromium	182	ug/L
Chrysene	11.6	ug/L
Indeno(1,2,3-CD)pyrene	1	ug/L
Nitrate	58400	ug/L
Phenanthrene	1	ug/L
Sodium	5000	ug/L

1 Acceptable groundwater criteria are from Parsons Letter SP307:021795.03 from P. Nixon to A. Ledford dated February 17, 1995 (See column labeled Comparison Criteria).

2 Acceptable groundwater criteria for the cesium isotopes are equivalent to 4 mrem/yr assuming 2 liters of daily intake.

TABLE B-2

GROUNDWATER MONITORING WELLS USED IN THE MODEL CALIBRATION ROCKY FLATS, COLORADO

Upgradient Wells	Under-Source Wells	Downgradient Wells
P207489	P209089	P209589
P209389	P210289	P209889
2486	P208989	
	P209489	
	05193	
	3086	
	2886	
	2786	

TABLE B-3

INPUT PARAMETERS USED IN THE ECTRAN MODEL
ROCKY FLATS, COLORADO

Parameter	Calibration	WAC Development
Source Area Size Length (ft) Width (ft)	 590 390	 650 865
Unsaturated Zone Thickness (ft)	3	3
Saturated Zone Thickness (ft)	5	5
Soil Density (g/cm^3)	1.7	1.7
Porosity	0.338	0.338
Hydraulic Conductivity[1] (ft/yr)	141	141
Infiltration (in/yr)	1	0.0068 to 2.5
Flow in the Unsaturated Zone(Used to Simulate the Fluctuation of the Groundwater Table[2] (L/day)	1490	3640
Flow in the Saturated Zone[3] (L/day)	1370	3050
Groundwater Velocity[4] (ft/yr)	26.7	26.7

1 Hydraulic conductivity from previous modeling at the SEPs.

2 Flow in the unsaturated zone was calibrated using tritium. The flow volume was adjusted for the WAC development to account for the change in source area size.

3 Flow based on groundwater velocity, saturated zone thickness, and width of source area.

4 Groundwater flow velocity based on hydraulic conductivity and the average gradient in the model area from the mean seasonal high groundwater elevations.

TABLE B-4

CALIBRATED SOIL/WATER PARTITIONING COEFFICIENTS (K_ds), LITERATURE VALUES, AND CALCULATED VALUES FROM LYSIMETER DATA ROCKY FLATS, COLORADO

Constituent of Concern	Calibrated Kd Unsaturated Zone, L/kg	Calibrated Kd Saturated Zone, L/kg	Literature Value[1] L/kg	Literature Value[2] L/kg	Kd Calculated From Lysimeter Data, L/kg[3]	Number of Lysimeter Data Pairs Used to Calculate K_d	Half-Life (Years)
Americium-241	100	10	8.2 - 3 x 10^5	700	NA[4]	NA	432
Arsenic	2	0.5	--[6]	200	NA	NA	--
Beryllium	5	1	250	650	NA	NA	--
Cadmium	5	1	2.7 - 625	6.5	597	2	--
Cesium-134	1	0.1	40-3968	1000	NA	NA	2.05
Cesium-137	1	0.1	40-3968	1000	NA	NA	30.2
Chromium	35	1.5	1.7-1729	850	NA	NA	--
Nitrate	0.01	0.01	--[5]	--[5]	0.127	11	--
Plutonium-239/240	100	20	27-36000	4500	NA	NA	24,100
Radium-226	690	106	57-21000	450	690	1	1,600
Sodium	10	1.5	--[6]	100	NA	NA	--
Uranium-233/234	17	2	0.03-2200	450	19.8	8	245,000
Uranium-235	17	2	0.03-2200	450	NA	NA	7.04 x 10^8
Uranium-238	17	2	0.03-2200	450	14.5	7	4.47 x 10^9

1 Thibault et al., 1990
2 Baes et. al., 1984
3 Value represents the geometric mean of the calculated Kd values from the pairs of water/soil concentrations
4 Not Applicable; No pairs of data were available to calculate Kd values
5 Values for Nitrate were not reported in these sources. A Kd value of 0 was used for Nitrate in previous modeling at the SEPs.
6 Values were not reported in this source.

TABLE B-5

K_d VALUES USED FOR RADIOLOGICAL COCs
AT OTHER DOE FACILITIES[1]
ROCKY FLATS, COLORADO

COC	Oak Ridge L/kg	Savannah River Site L/kg	Hanford Site L/kg	Idaho National Engineering Laboratory (unsat'd) L/kg	Idaho National Engineering Laboratory (sat'd) L/kg	Fernald Environmental Management Project (unsat'd) L/kg	Fernald Environmental Management Project (sat'd) L/kg	Rocky Flats Environmental Technology Site (Unsat'd) L/kg	Rocky Flats Environmental Technology Site (Sat'd) L/kg
Americium-241	40	150	100	NA	NA	100	10	100	10
Cesium-137	3000	100	1	20	20	1810	1370	1	0.1
Plutonium-239/240	40	100	100	2000	200	1700	100	100	20
Radium-226	3000	500	10	50	5	696	106	690	106
Uranium-233/234	40	50	0	1000	100	3.1	1.78	17	2
Uranium-235	40	50	0	1000	100	3.1	1.78	17	2
Uranium-238	40	50	0	1000	100	3.1	1.78	17	2

1 All data except RFETS data from the draft table "Comparison of K_d Values" DOE Disposal Working Group, Performance Evaluations for Mixed Low-Level Waste, 1995.

TABLE B-6

ORGANIC K_d VALUES AND HALF-LIVES
ROCKY FLATS, COLORADO

Constituent of Concern	K_{OW}	Reference	K_d (3) L/kg	Half Life, Yrs (4)
Arochlor-1254	1.07×10^6	(1)	3.10×10^3	NA (5)
Benzo(a)anthracene	4.00×10^5	(2)	1.16×10^3	3.73
Benzo(a)pyrene	9.55×10^5	(2)	2.77×10^3	2.90
Benzo(b)fluoranthene	3.72×10^6	(2)	1.08×10^4	3.34
Benzo(g,h,i)perylene	1.70×10^7	(2)	4.93×10^4	3.60
Benzo(k)fluoranthene	6.92×10^6	(2)	2.01×10^4	11.7
Bis(2-ethylhexyl)phthalate	2.00×10^5	(2)	5.78×10^2	1.07
Chrysene	4.00×10^5	(2)	1.16×10^3	5.48
Indeno(1,2,3-cd)pyrene	4.57×10^7	(2)	1.32×10^5	4.00
Phenanthrene	2.90×10^4	(2)	8.40×10^1	1.10

1 USEPA, " Treatability Data Base" Risk Reduction Engineering Laboratory.
2 RCRA Handbook of Groundwater Monitoring Constituents, 1992.
3 K_d's are calculated based on the following equations from (Maidment, 1990)
$K_d = K_{OC} \times F_{OC}$ where $F_{OC} = 0.0046$ (DOE 1995, Page II.3-197) and
$K_{OC} = 0.63 \times K_{OW}$ (Maidment, 1990).
4 Howard et. al. 1991.
5 Half-life not available from literature, in the WAC development it was conservatively assumed that Arochlor-1254 does not decay.

TABLE B-7

WAC FOR SCENARIO 1
0.0068 AND 1 INCH OF INFILTRATION PER YEAR
ROCKY FLATS, COLORADO

COC	Unit	WAC for Scenario 1 0.0068 in/yr Infiltration	WAC for Scenario 1 1 in/yr Infiltration
Am-241	pCi/L	17,100	74.5
Cs-134	pCi/L	3,510,000	12,800
Cs-137	pCi/L	111,000	737
Pu-239/240	pCi/L	1,070	4.43
Ra-226	pCi/L	117,000	415
U-233/234	pCi/L	35,200	254
U-235	pCi/L	1,410	10.2
U-238	pCi/L	24,500	177
Arsenic	ug/L	13,600	142
Beryllium	ug/L	1,430	14.2
Cadmium	ug/L	5,190	51.8
Chromium	ug/L	142,000	881
Nitrate	mg/L	15,900	166
Sodium	mg/L	1,750	14.9
Arochlor-1254[1]	mg/L	17,200	59.1

1 The contaminant plumes of the other organic COCs did not reach POC at concentrations higher than the compliance criteria during the 1000-yr modeling time frame. Theoretically this would result in a pure product concentration for the WAC.

TABLE B-8

SUMMARY OF DETERMINISTIC SENSITIVITY ANALYSIS INPUT ROCKY FLATS, COLORADO

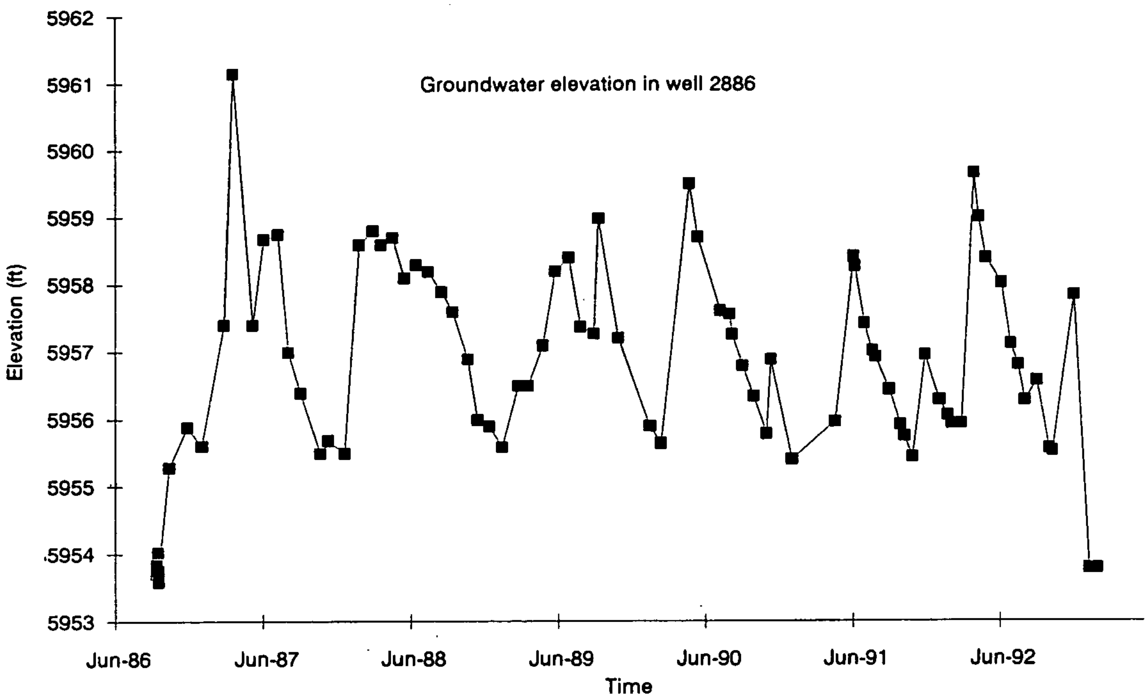
Input Parameter	Minimum	Maximum
Infiltration Rate (in/yr)	0.01	2.1
K_d (L/kg) *in Unsaturated Zone*	0.5	80
K_d (L/kg) in Saturated Zone	0.1	10
Additional Flow (L/Day) in Unsaturated Zone	1820	5460

TABLE B-9

SUMMARY OF PROBABILISTIC SENSITIVITY ANALYSIS INPUT AND RESULTS
ROCKY FLATS, COLORADO

Constant Source Loading of U-238 (WAC): 177 pCi/L

	Assumptions in Monte Carlo Simulation:								Monte Carlo Simulation Results:	
	Time of Barrier Layer Beginning to Lose Its Function (Year) Normal Distribution		Unsaturated Layer Kd (L/kg) Lognormal Distribution		Saturated Layer Kd (L/kg) Lognormal Distribution		Vertical Fluctuation Flow in Unsaturated Layer (L/Day) Uniform Distribution		Percentile of the Saturated Layer Concentration at 1000 yr Less Than Risk Criteria (51.6 pCi/L)	Percentile of the Saturated Layer Concentration at 200 yr Less than Risk Criteria (51.6 pCi/L)
	Mean	Standard Dev.	Mean	Standard Dev.	Mean	Standard Dev.	Minimum	Maximum		
Case 1	500	150	17	34	2	4	1820	5460	65%	100%
Case 2	700	150	17	34	2	4	1820	5460	88%	100%
Case 3	800	150	17	34	2	4	1820	5460	94%	100%
Case 4	Barrier Layer Keeps Its Function in 1000 Years		17	34	2	4	1820	5460	100%	100%



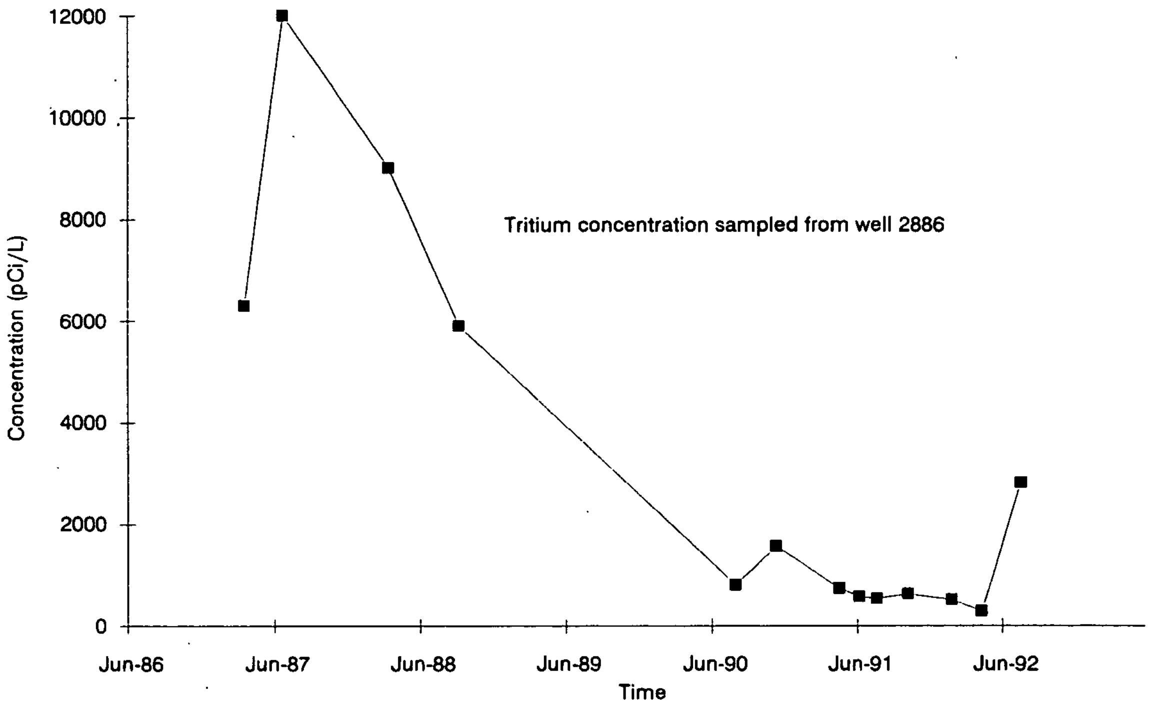
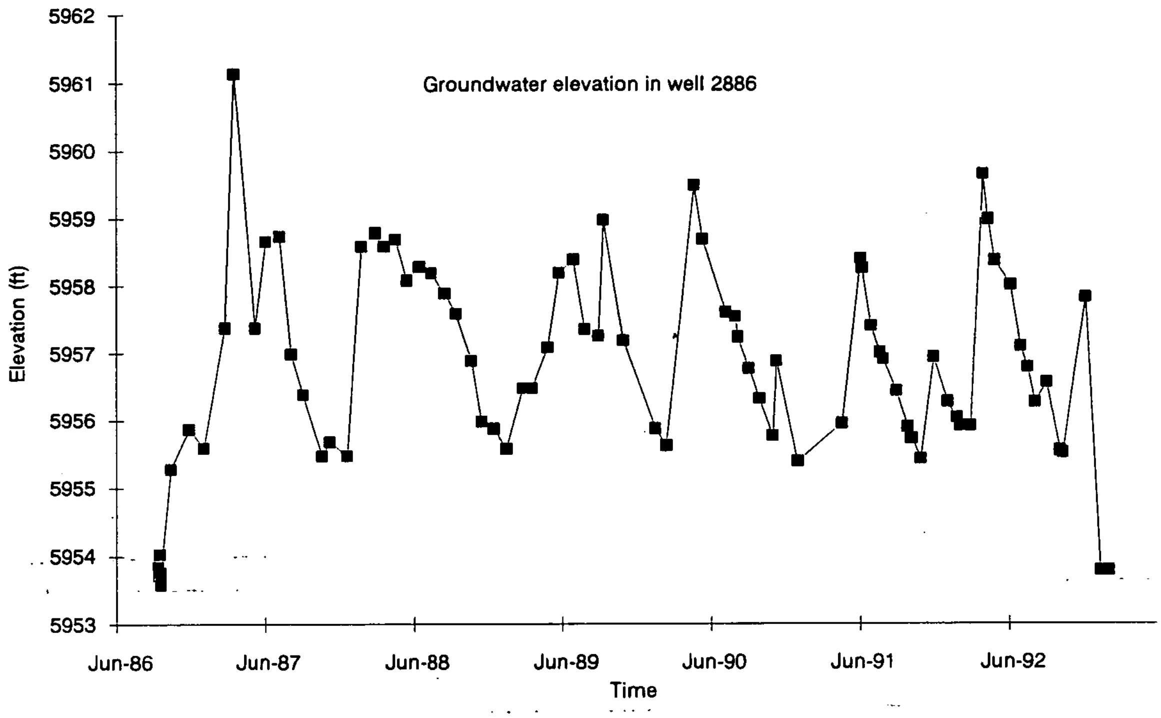


FIGURE B-1 TRITIUM CONCENTRATION VS. WATER ELEVATION IN WELL 2886



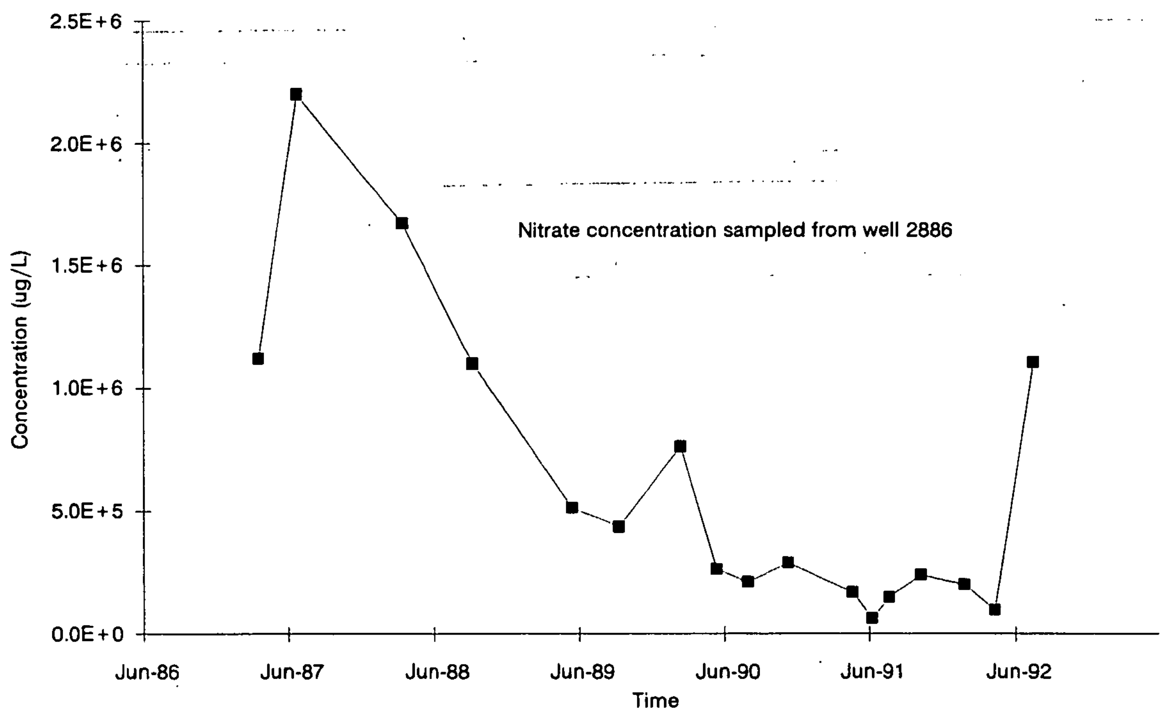
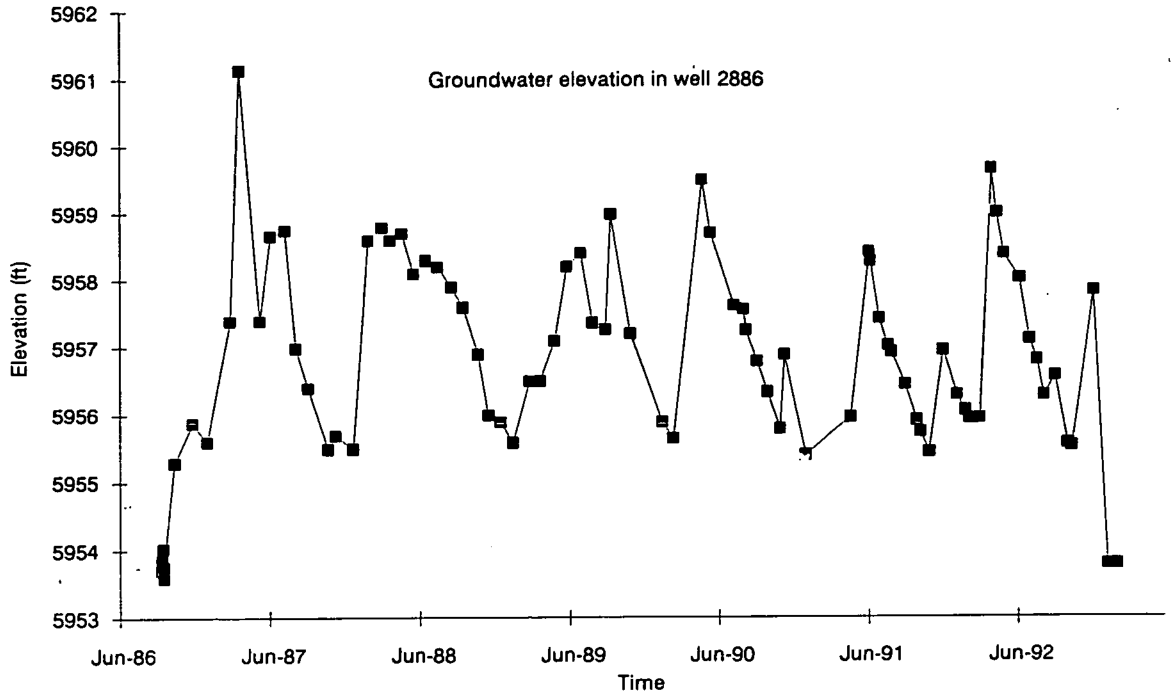


FIGURE B-2 NITRATE CONCENTRATION VS. WATER ELEVATION IN WELL 2886



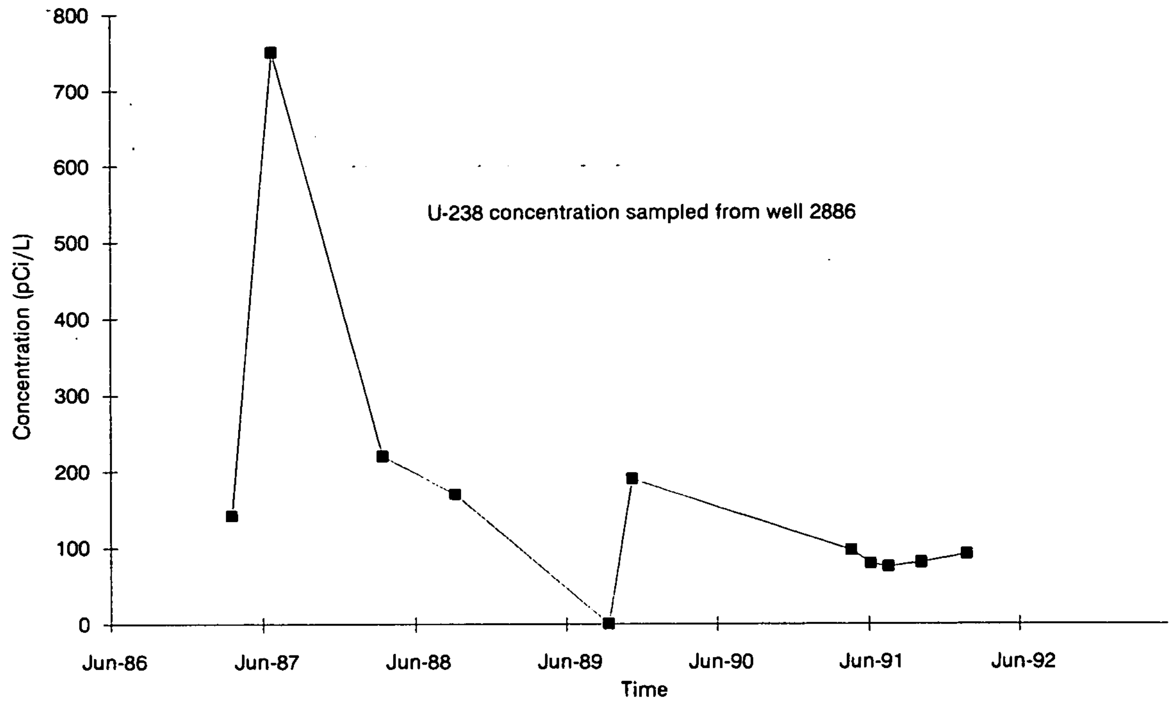
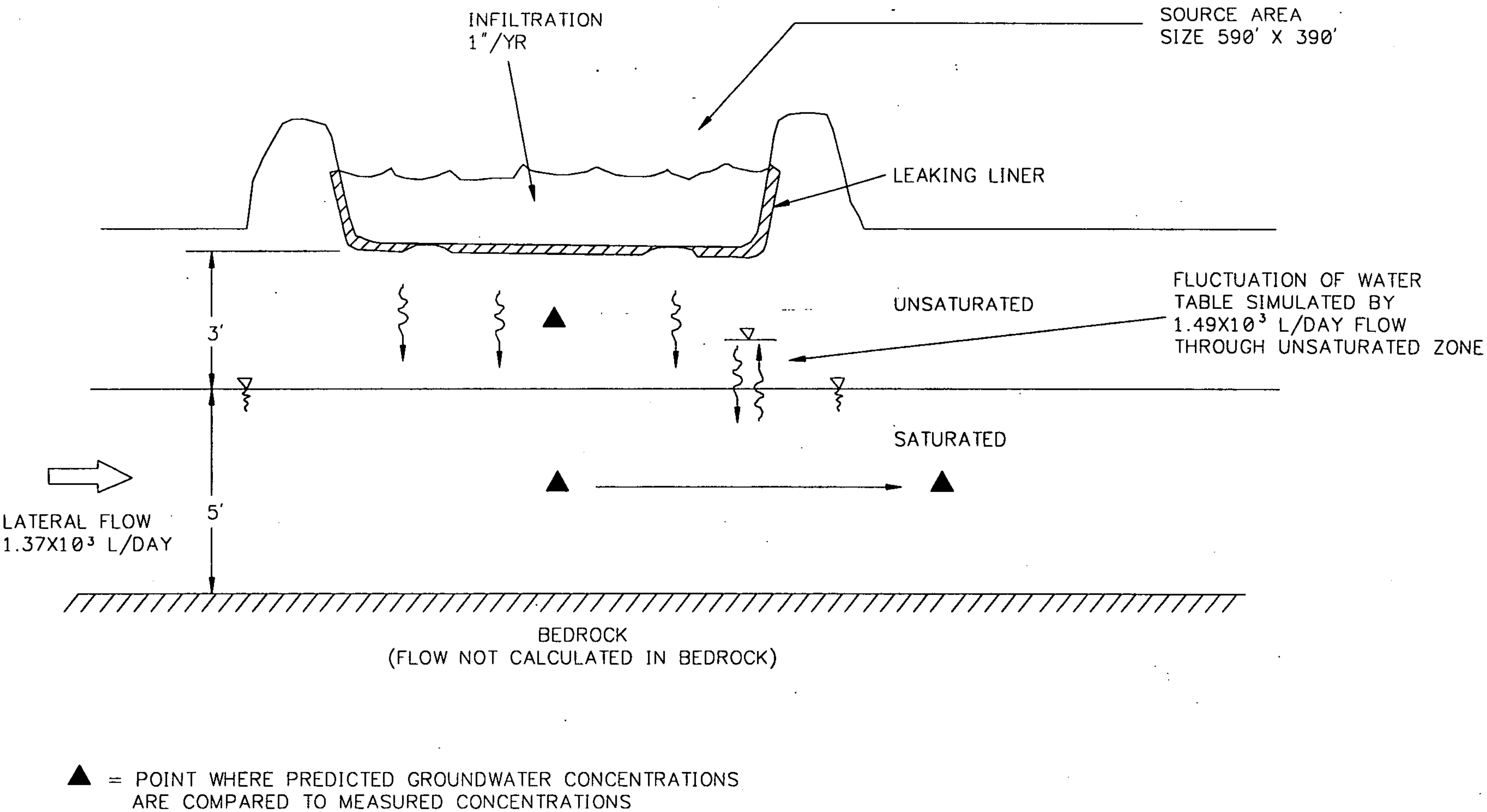


FIGURE B-3 URANIUM-238 CONCENTRATION VS. WATER ELEVATION IN WELL 2886

ACAD: O:\DATA\CADD\3A75\95040302.DWG 05/03/95 TD VIEW=1A



CALIBRATION CONCEPTUAL MODEL
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-5

Halliburton NUS
CORPORATION

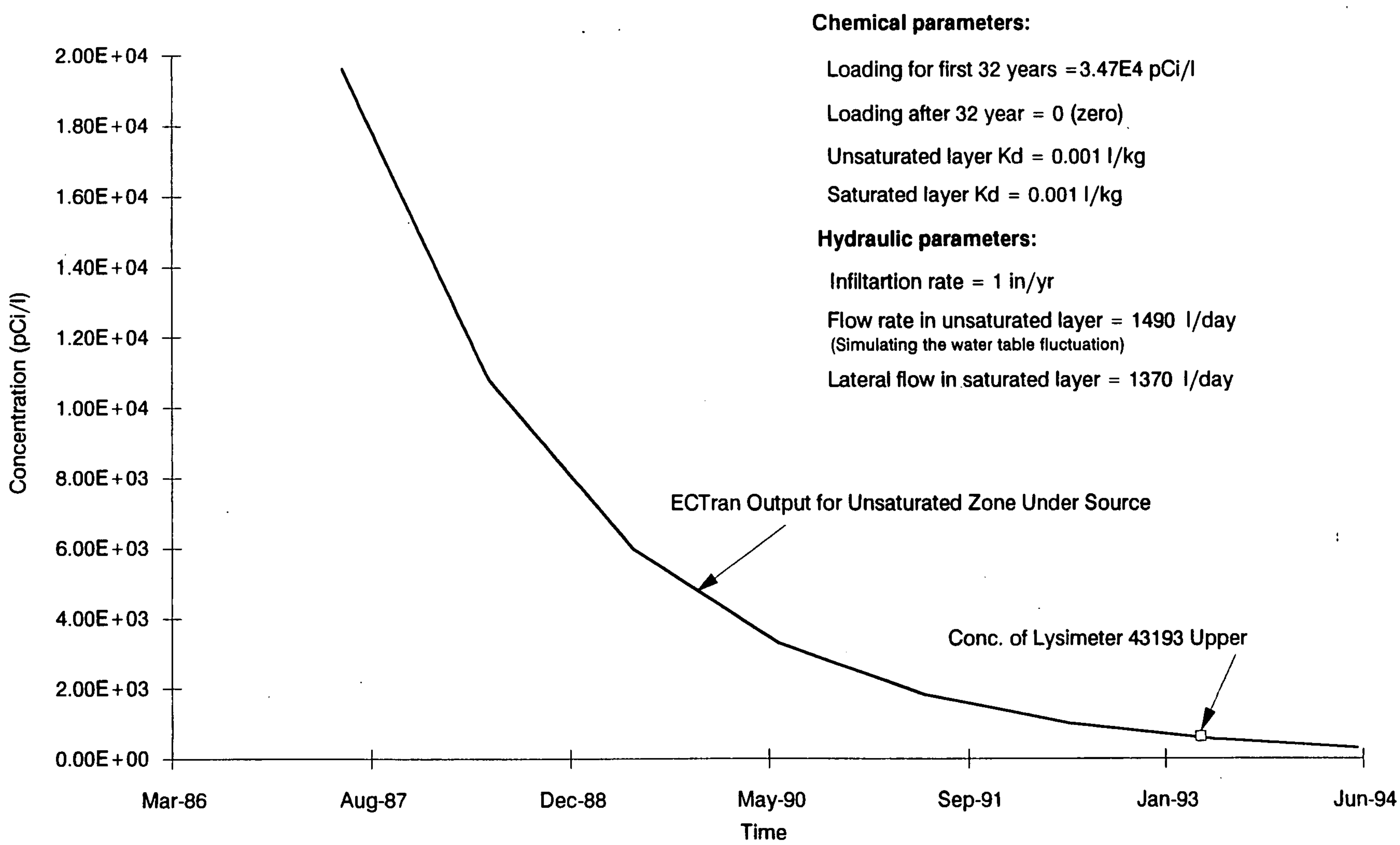


FIGURE B-6 TRITIUM CALIBRATION RESULTS IN THE UNSATURATED ZONE

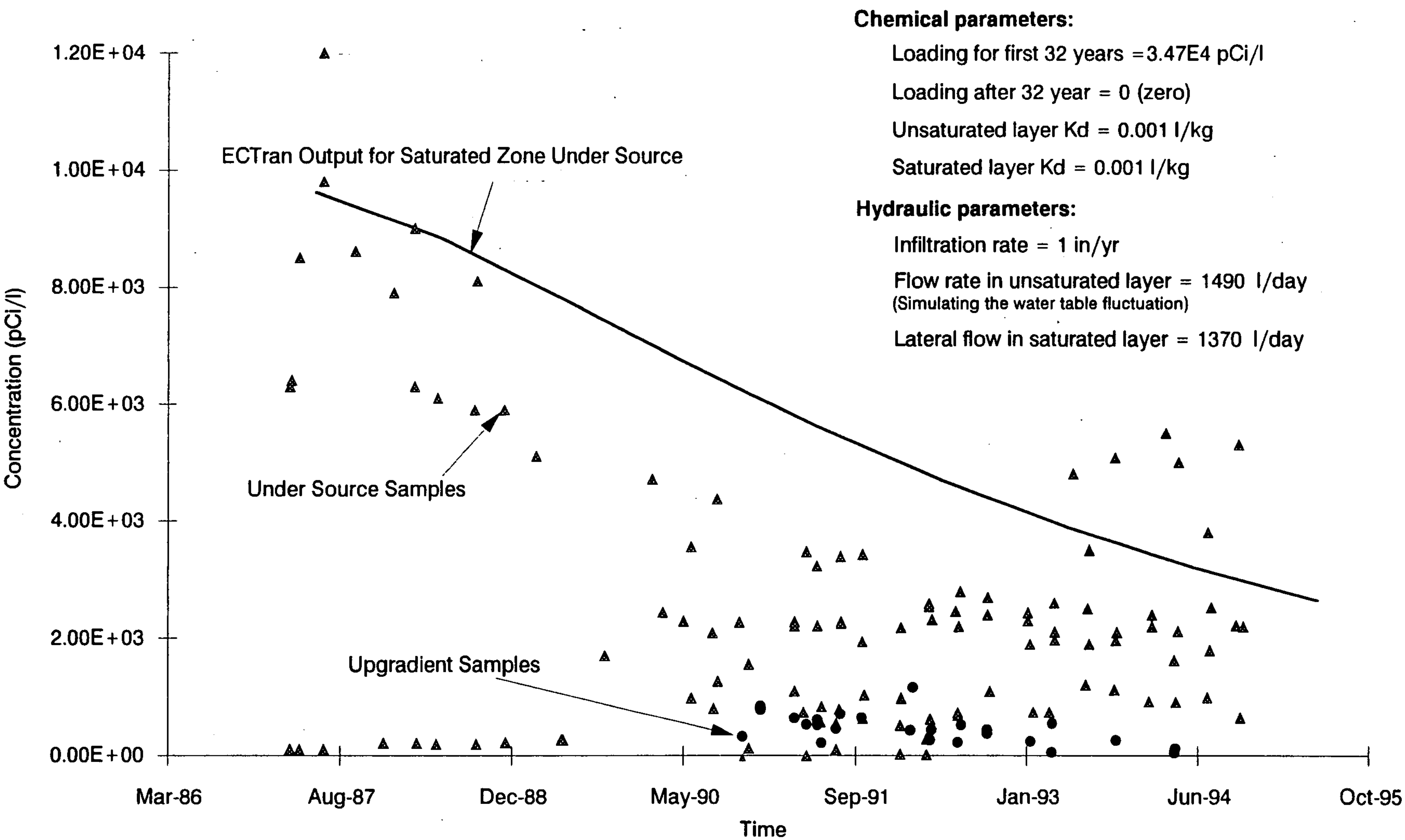


FIGURE B-7 TRITIUM CALIBRATION RESULTS IN THE SATURATED ZONE UNDER THE SOURCE

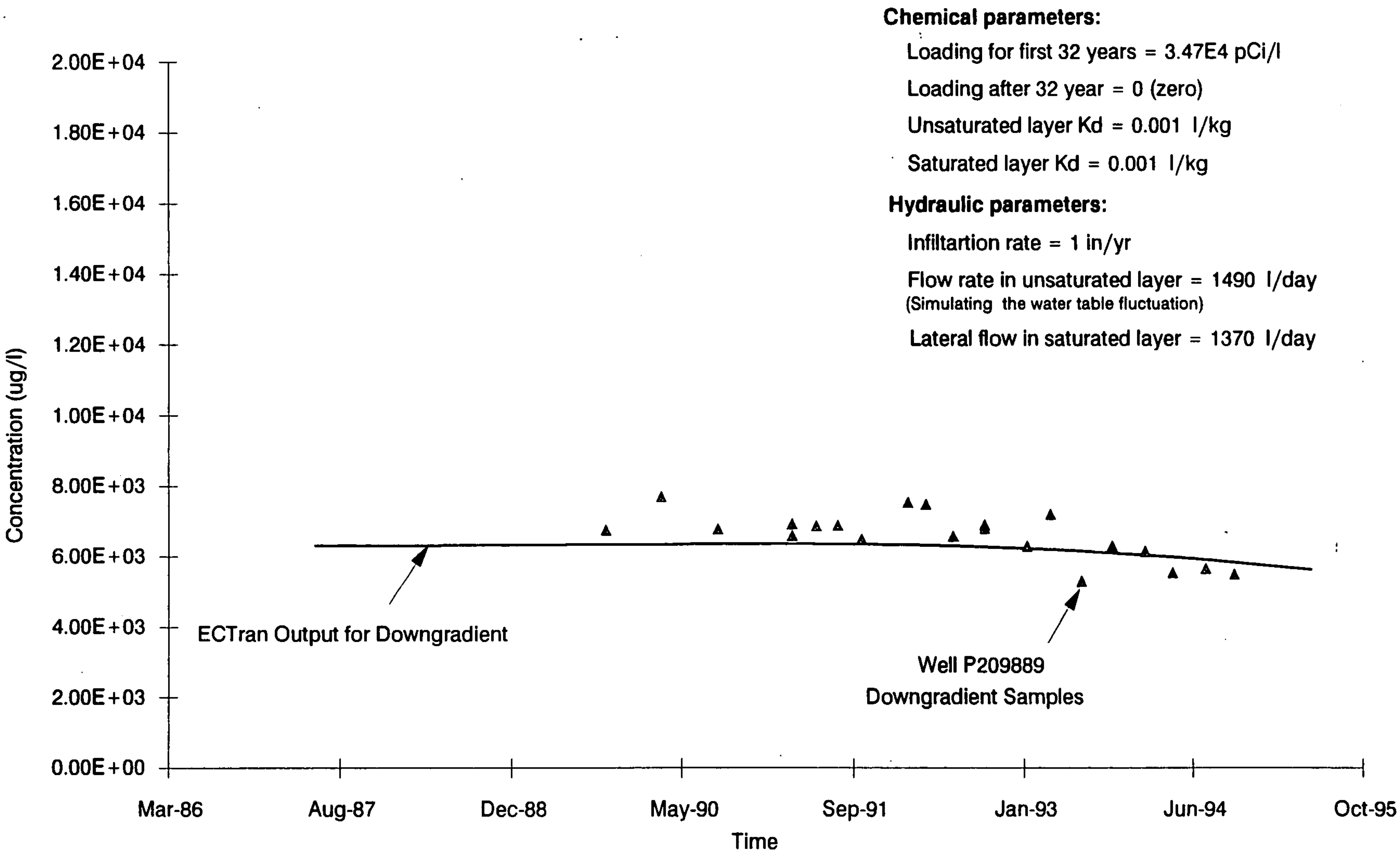


FIGURE B-8 TRITIUM CALIBRATION RESULTS IN THE SATURATED ZONE DOWN GRADIENT

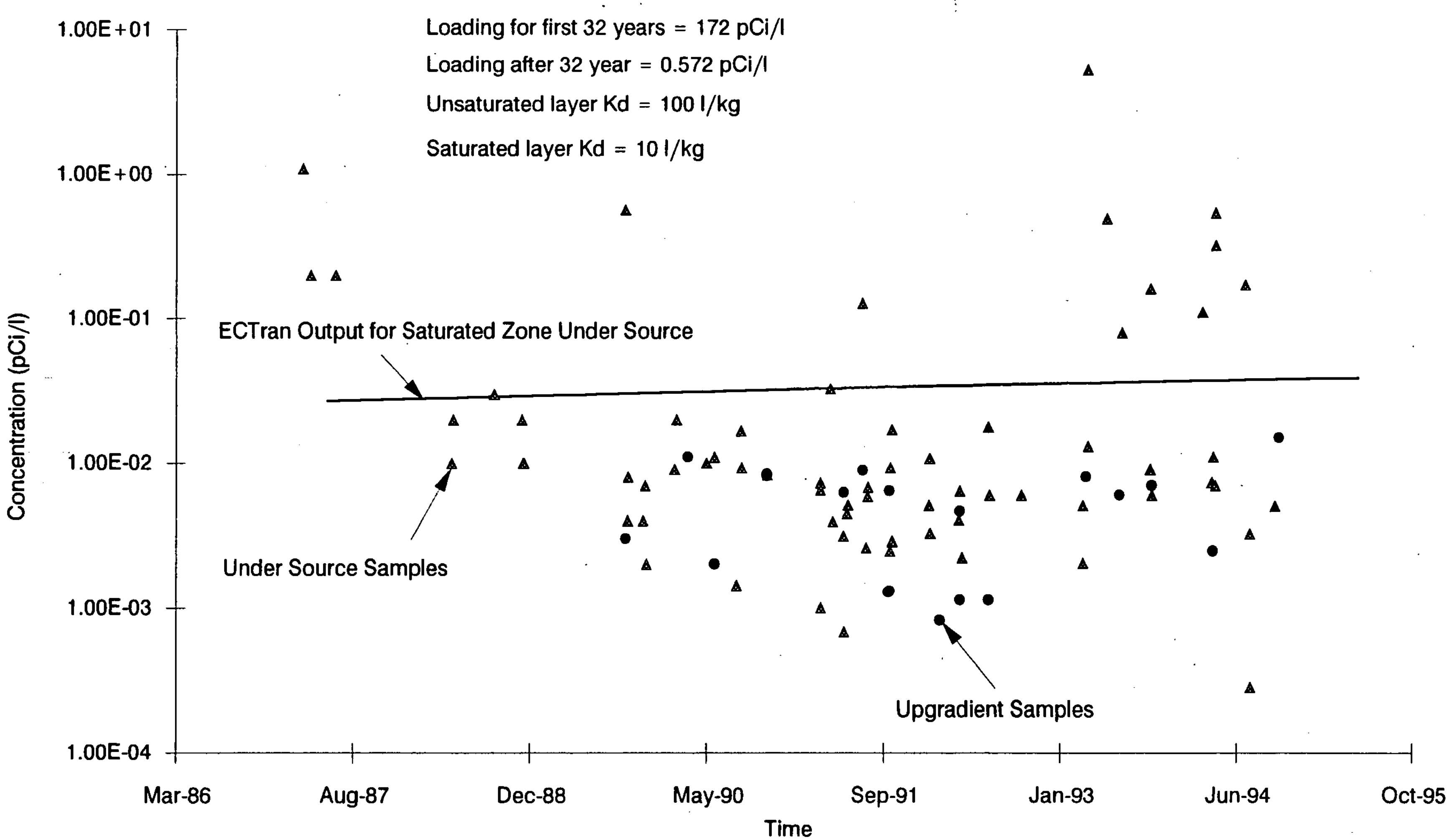


FIGURE B-9 AMERICIUM-241 CALIBRATION RESULTS

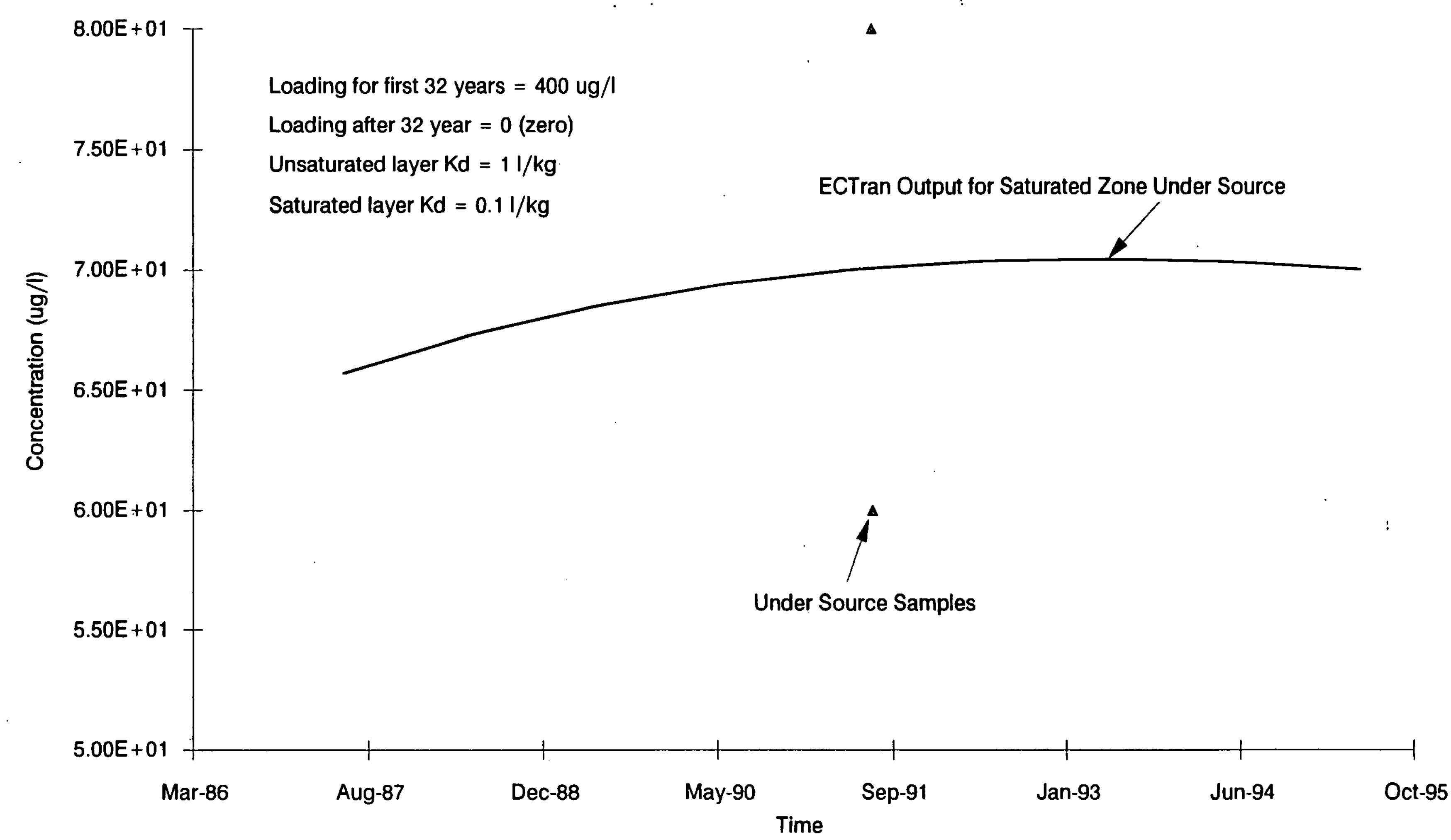


FIGURE B-10 CESIUM CALIBRATION RESULTS

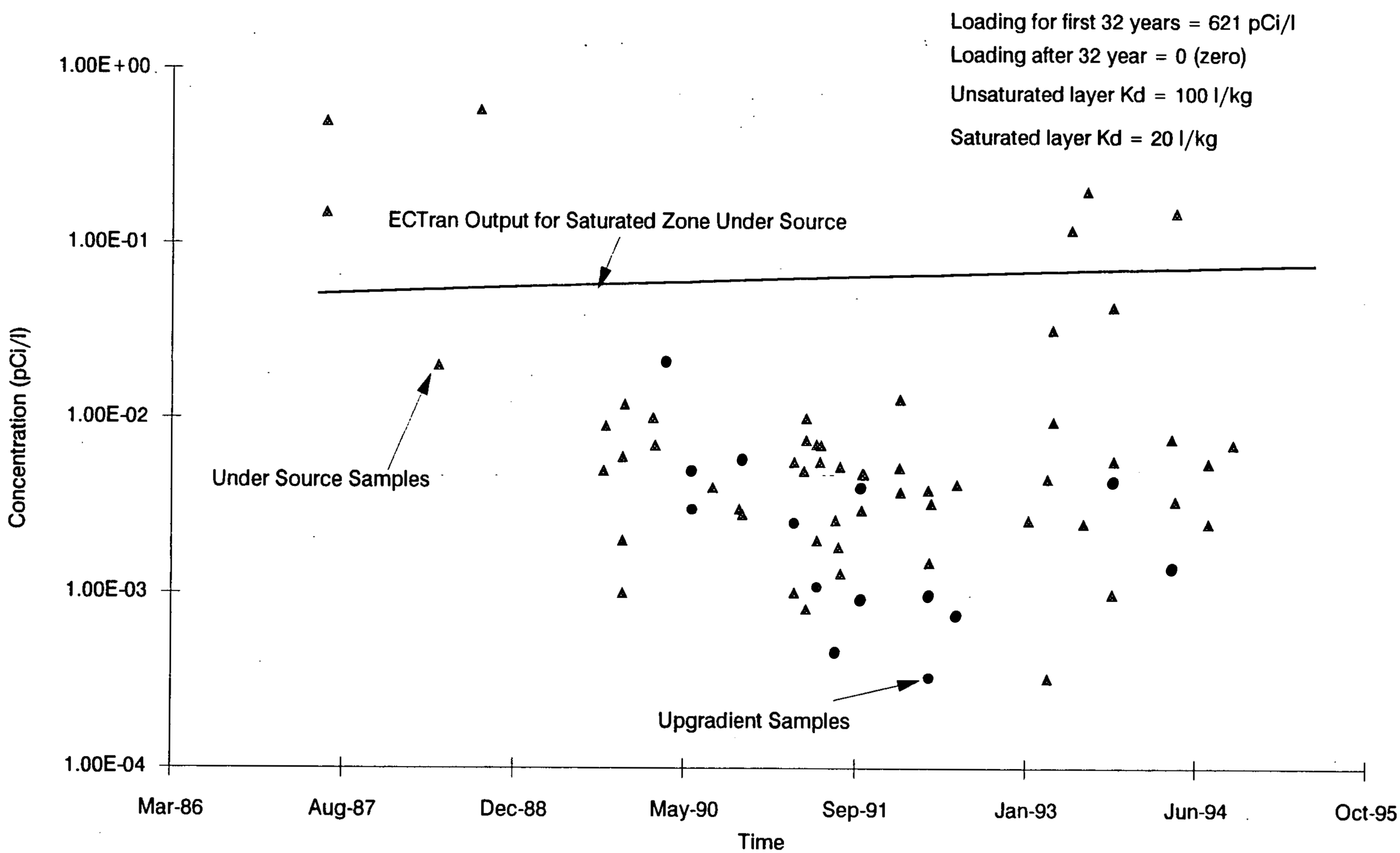


FIGURE B-11 PLUTONIUM-239/240 CALIBRATION RESULTS

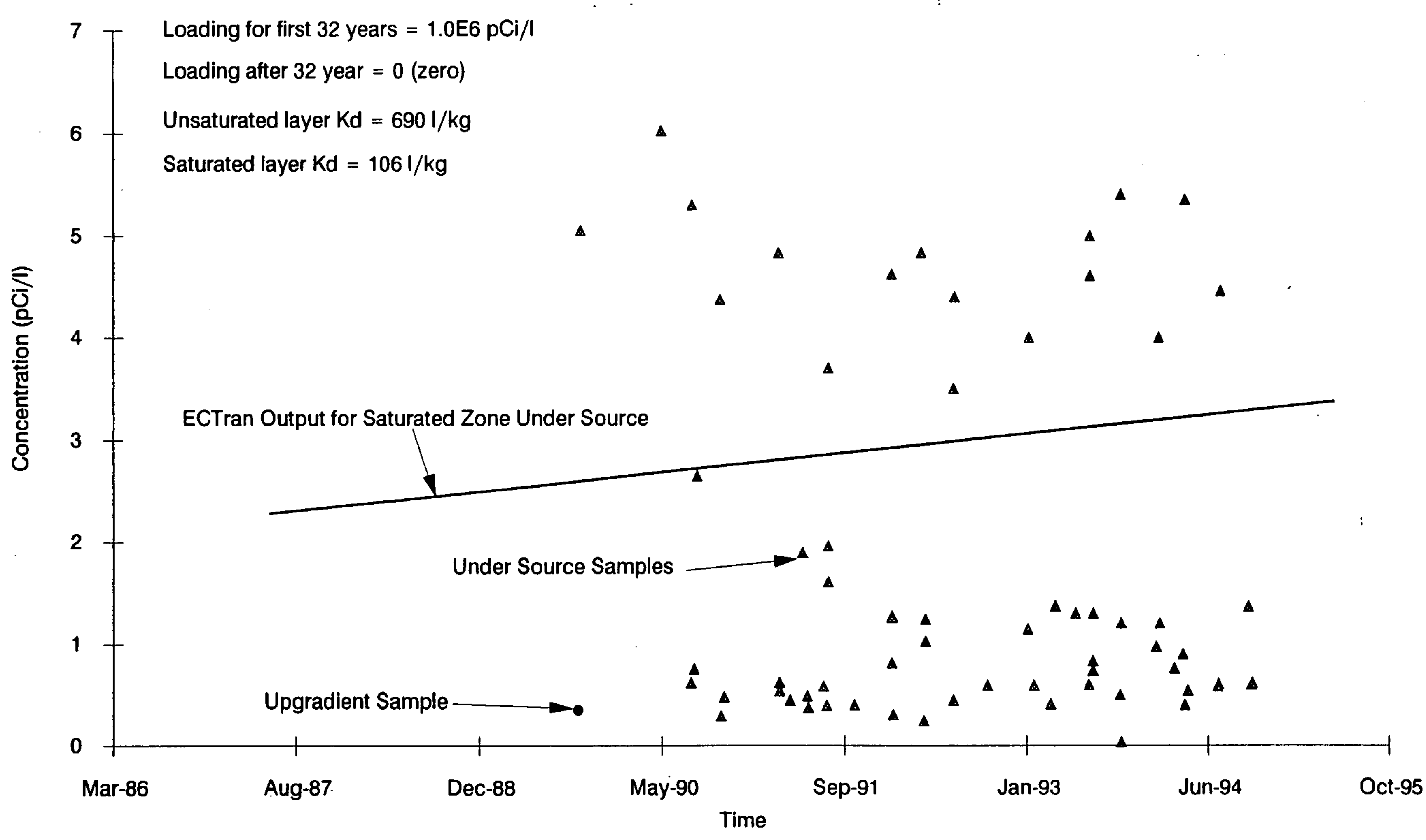


FIGURE B-12 RADIUM-226 CALIBRATION RESULTS

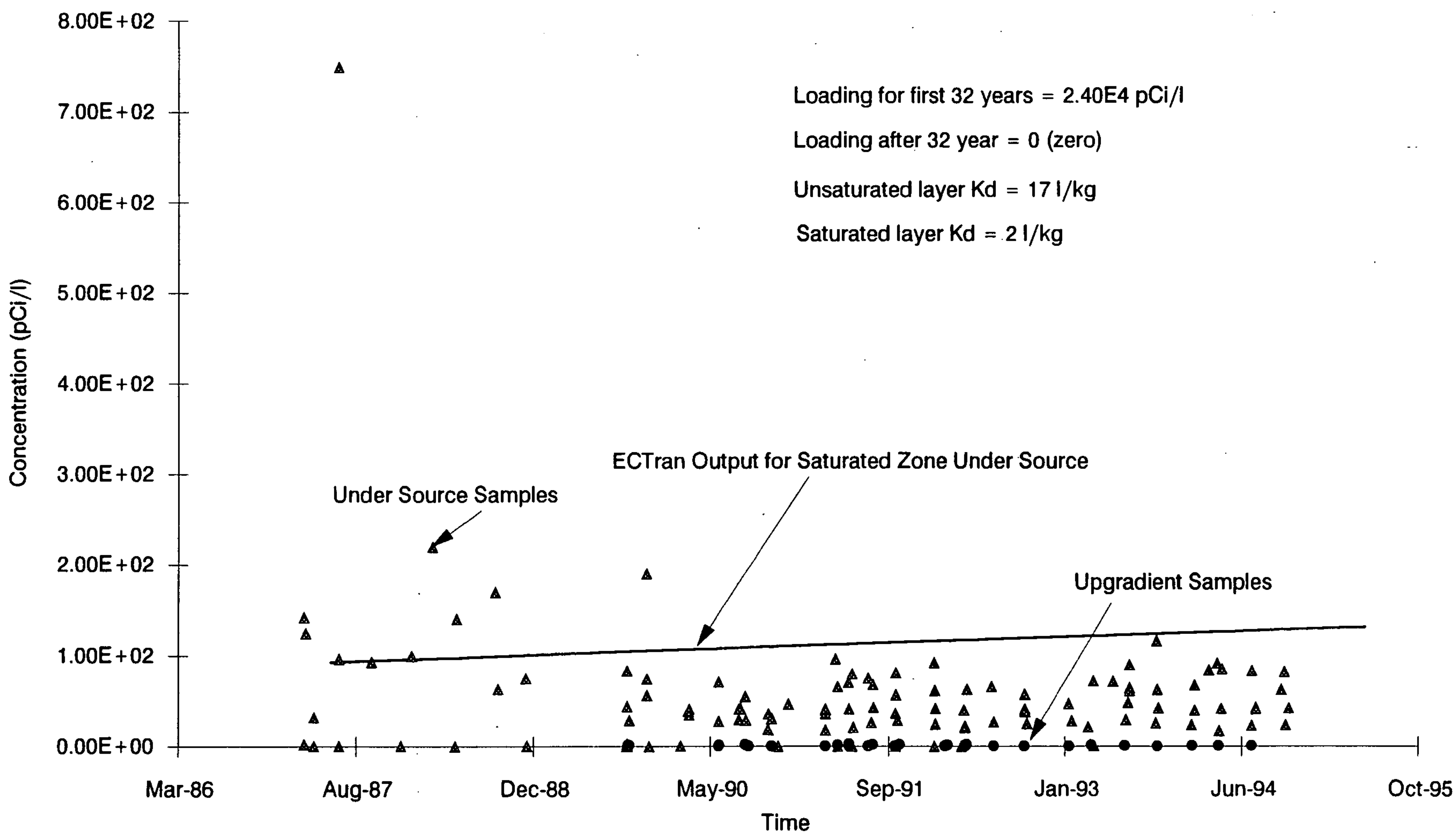


FIGURE B-13 URANIUM-238 CALIBRATION RESULTS

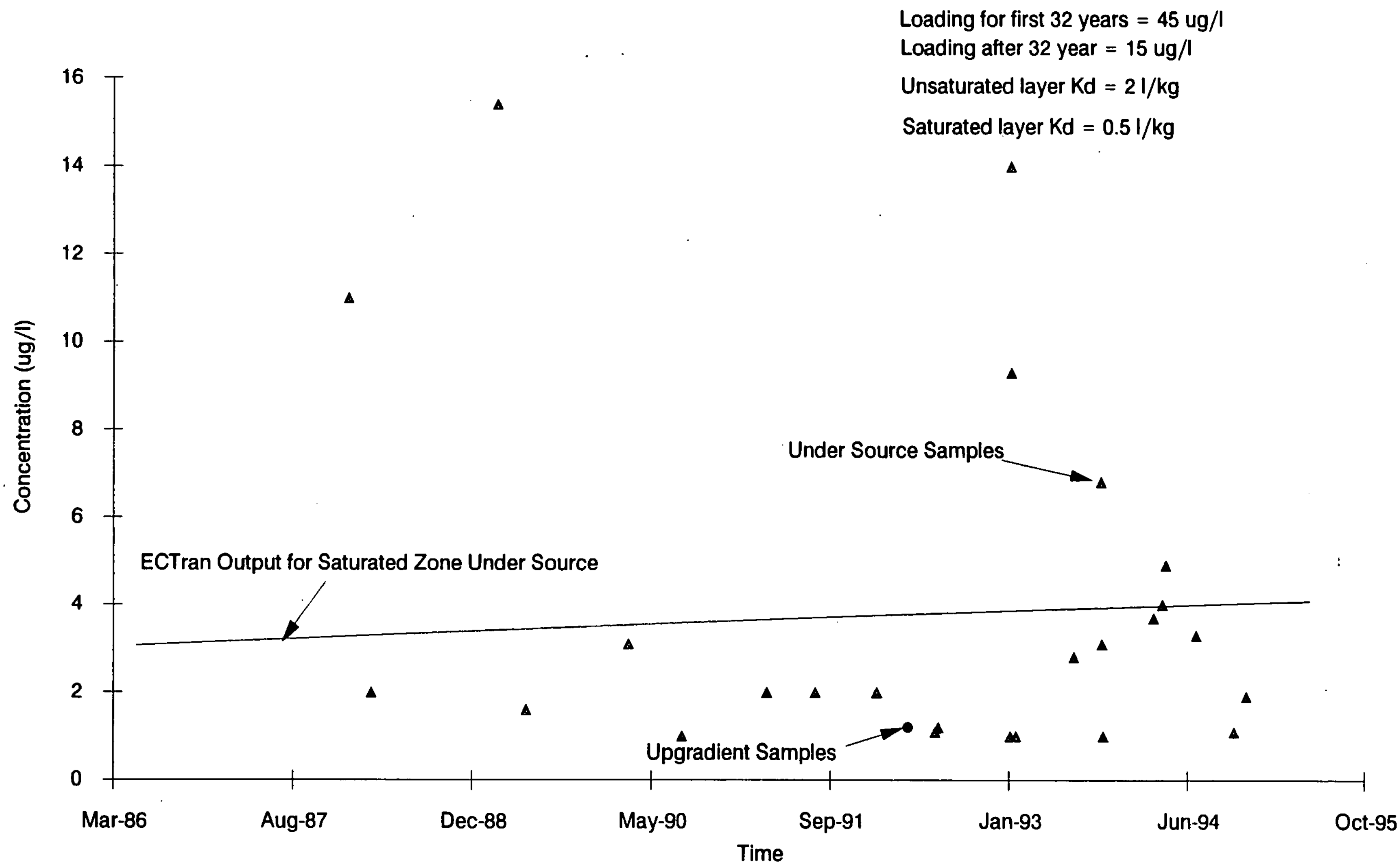


FIGURE B-14 ARSENIC CALIBRATION RESULTS

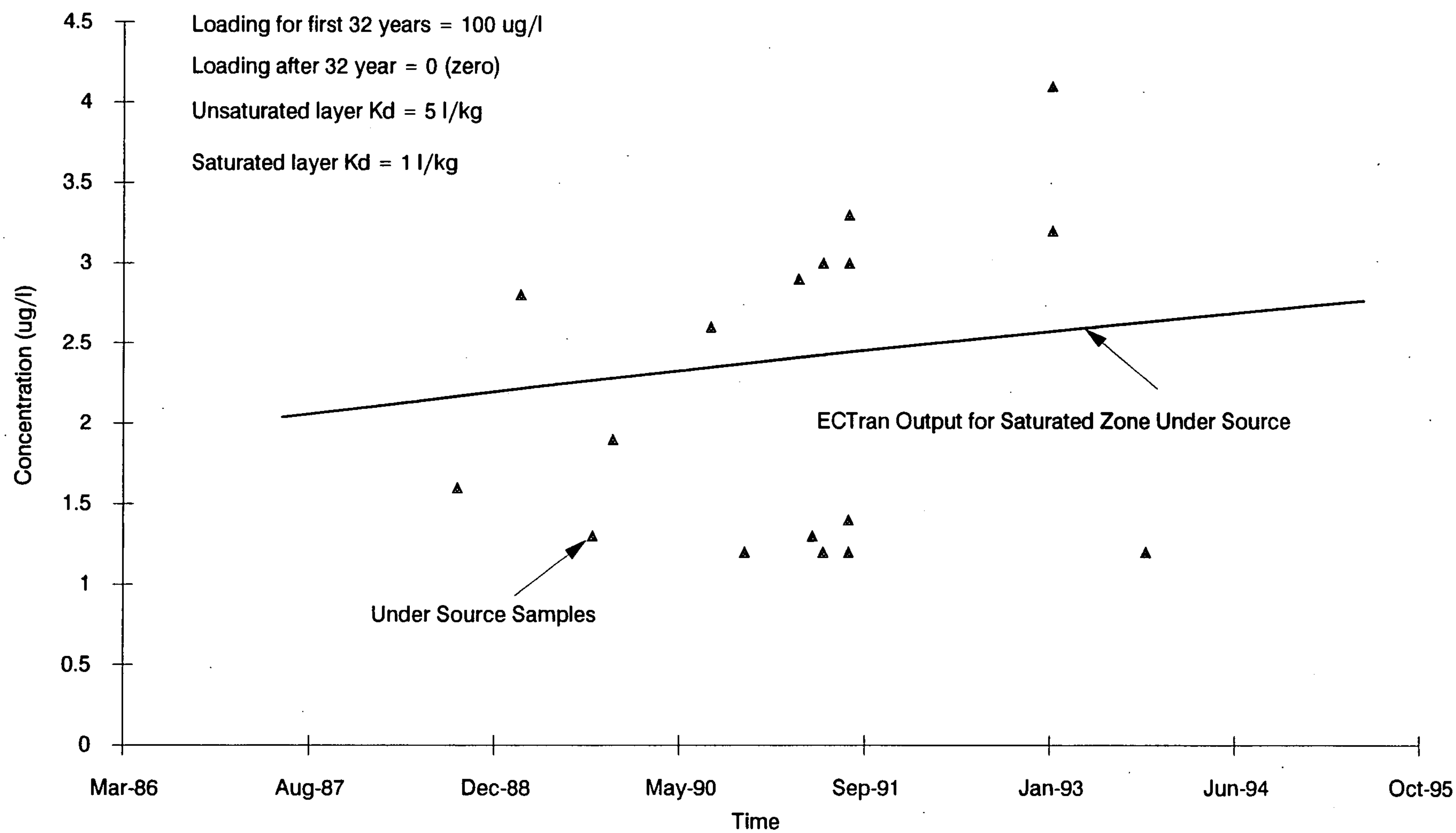


FIGURE B-15 BERYLLIUM CALIBRATION RESULTS

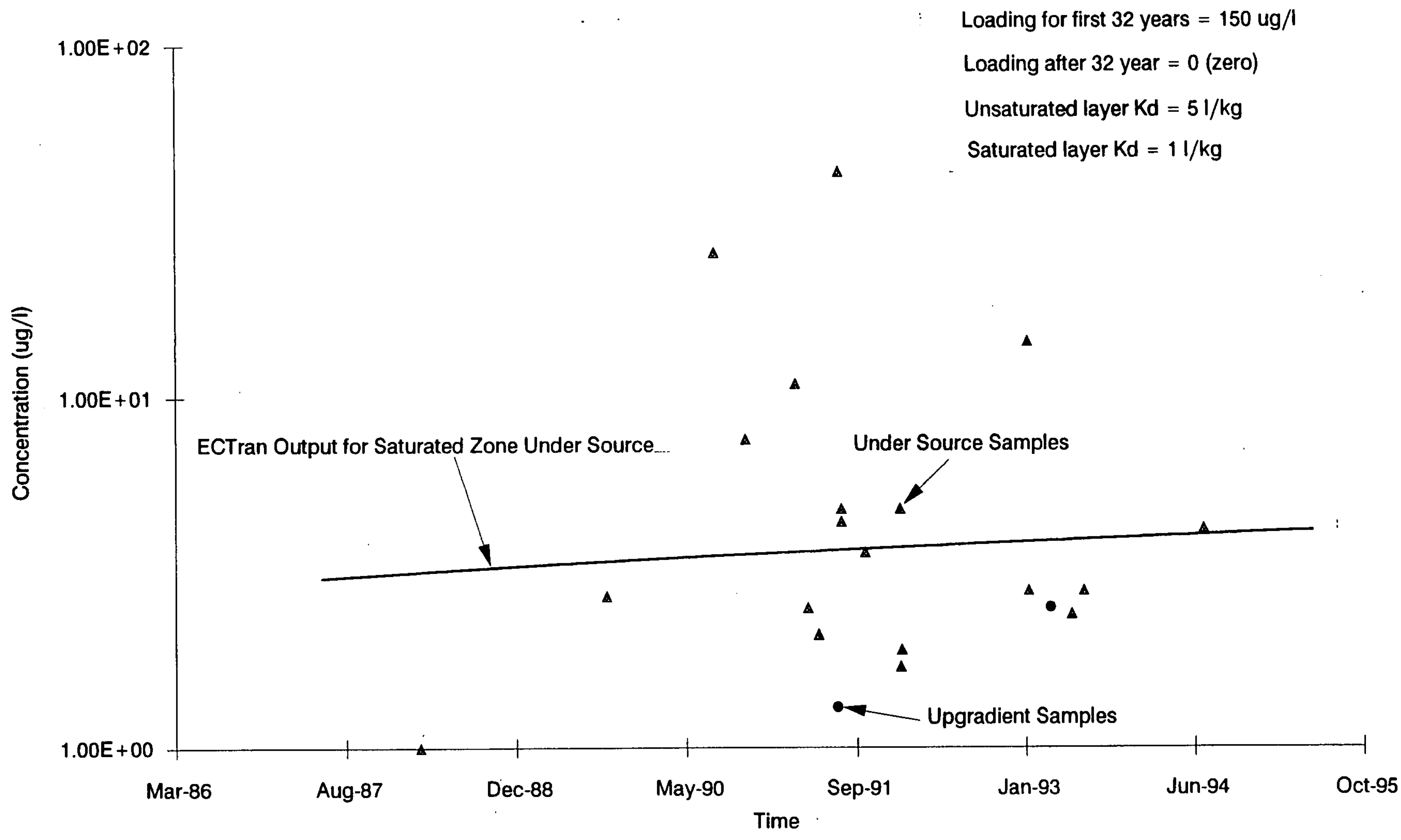


FIGURE B-16 CADMIUM CALIBRATION RESULTS

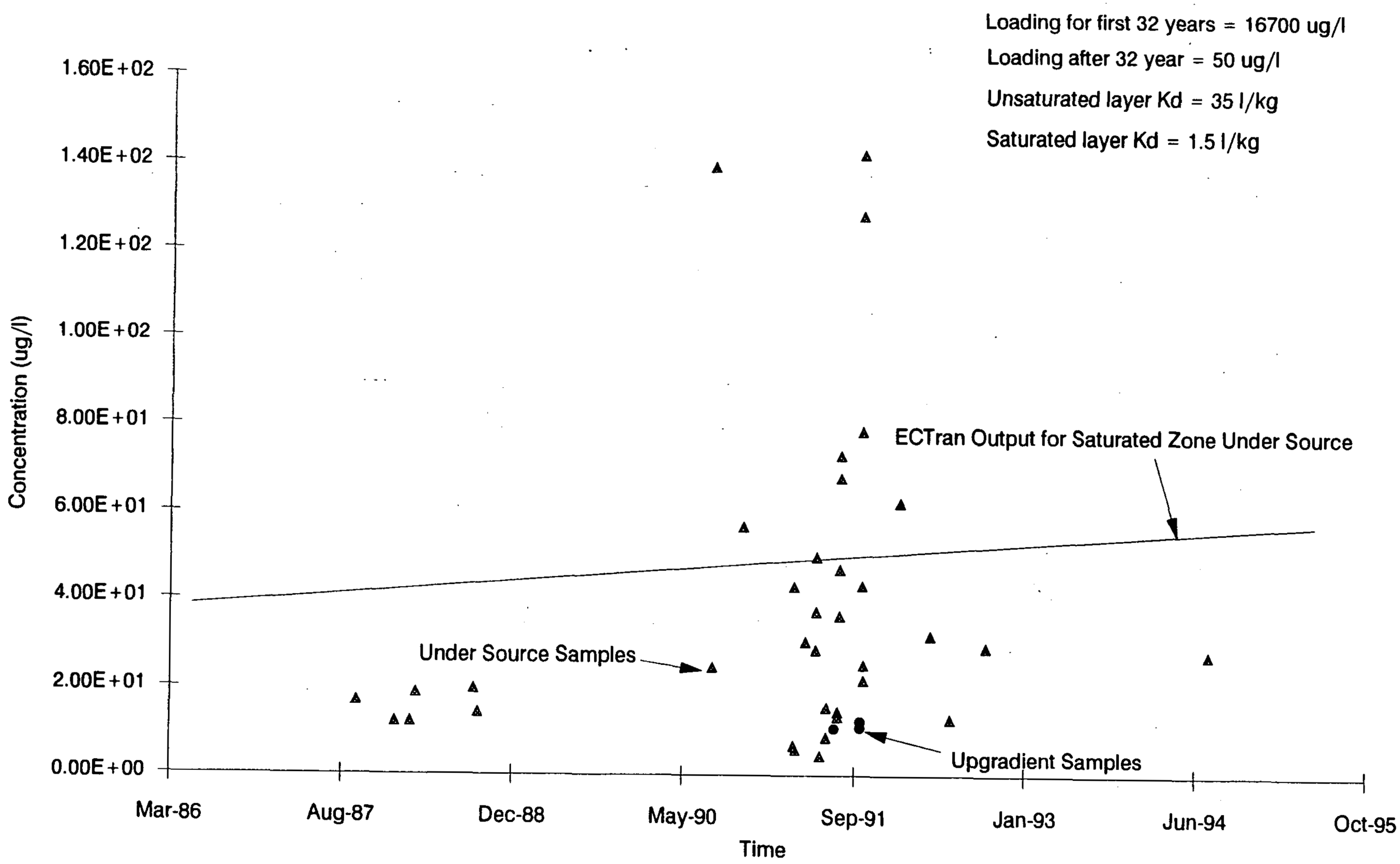


FIGURE B-17 CHROMIUM CALIBRATION RESULTS

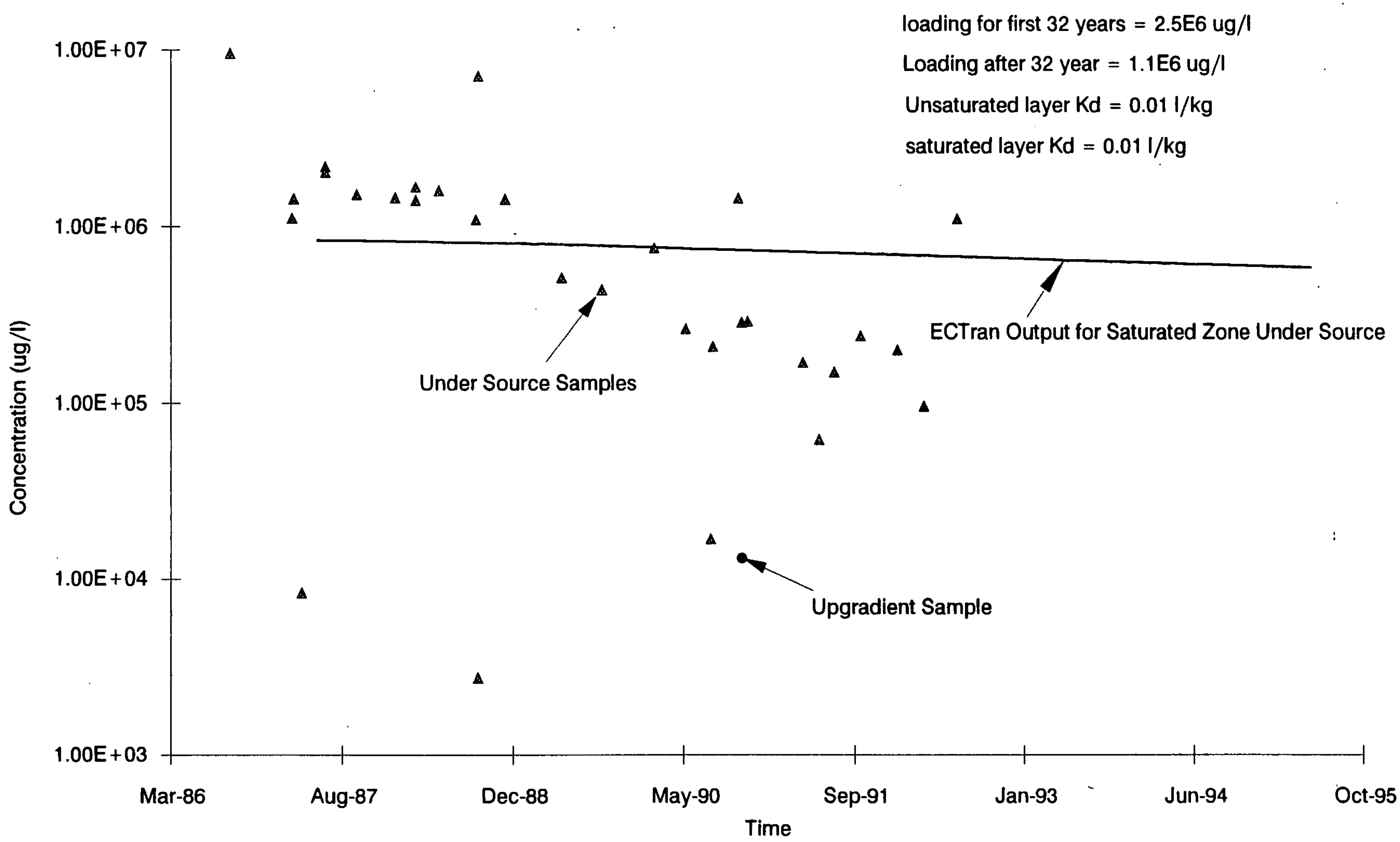


FIGURE B-18 NITRATE CALIBRATION RESULTS

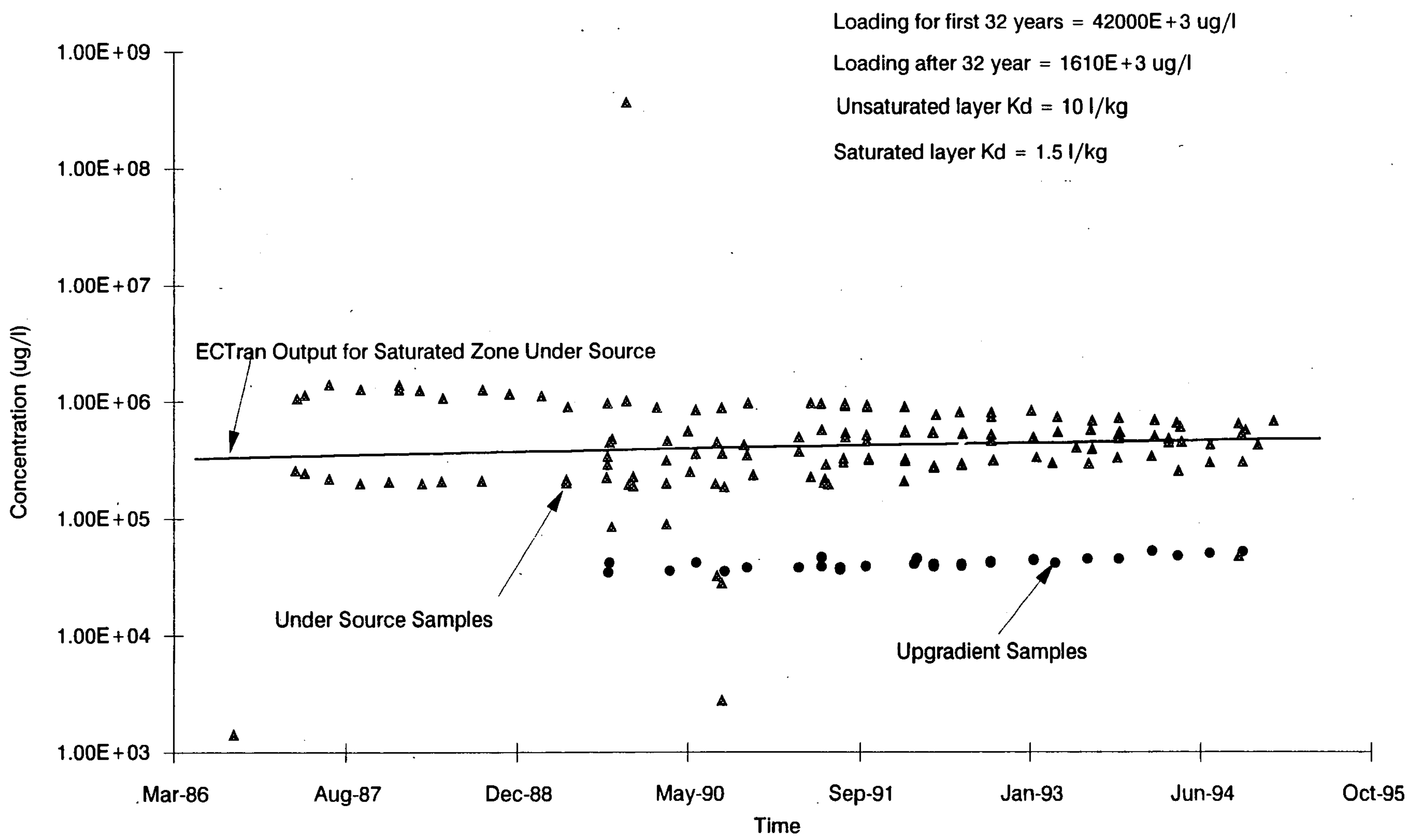
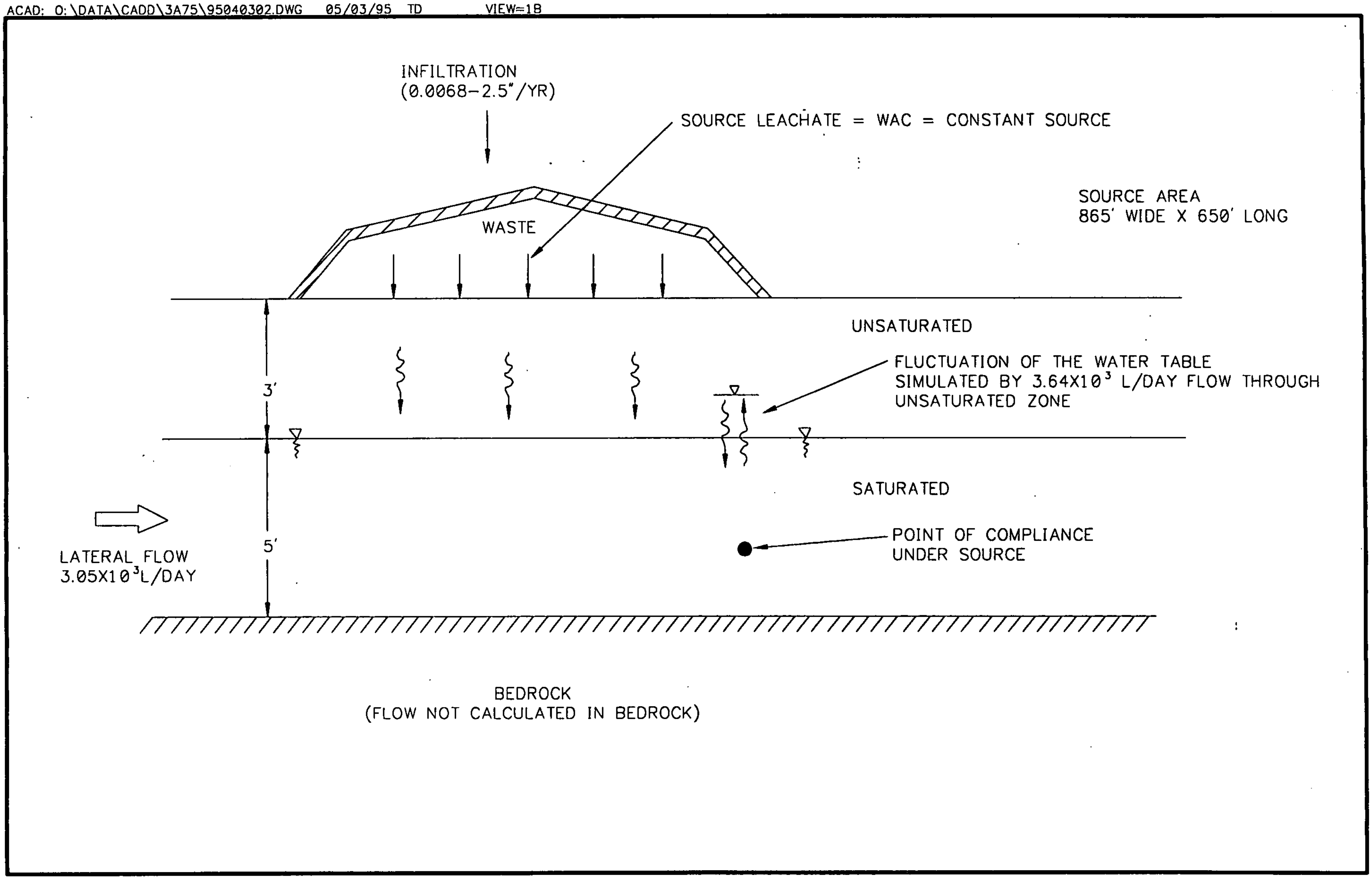


FIGURE B-19 SODIUM CALIBRATION RESULTS

ACAD: O:\DATA\CADD\3A75\95040302.DWG 05/03/95 TD VIEW=1B

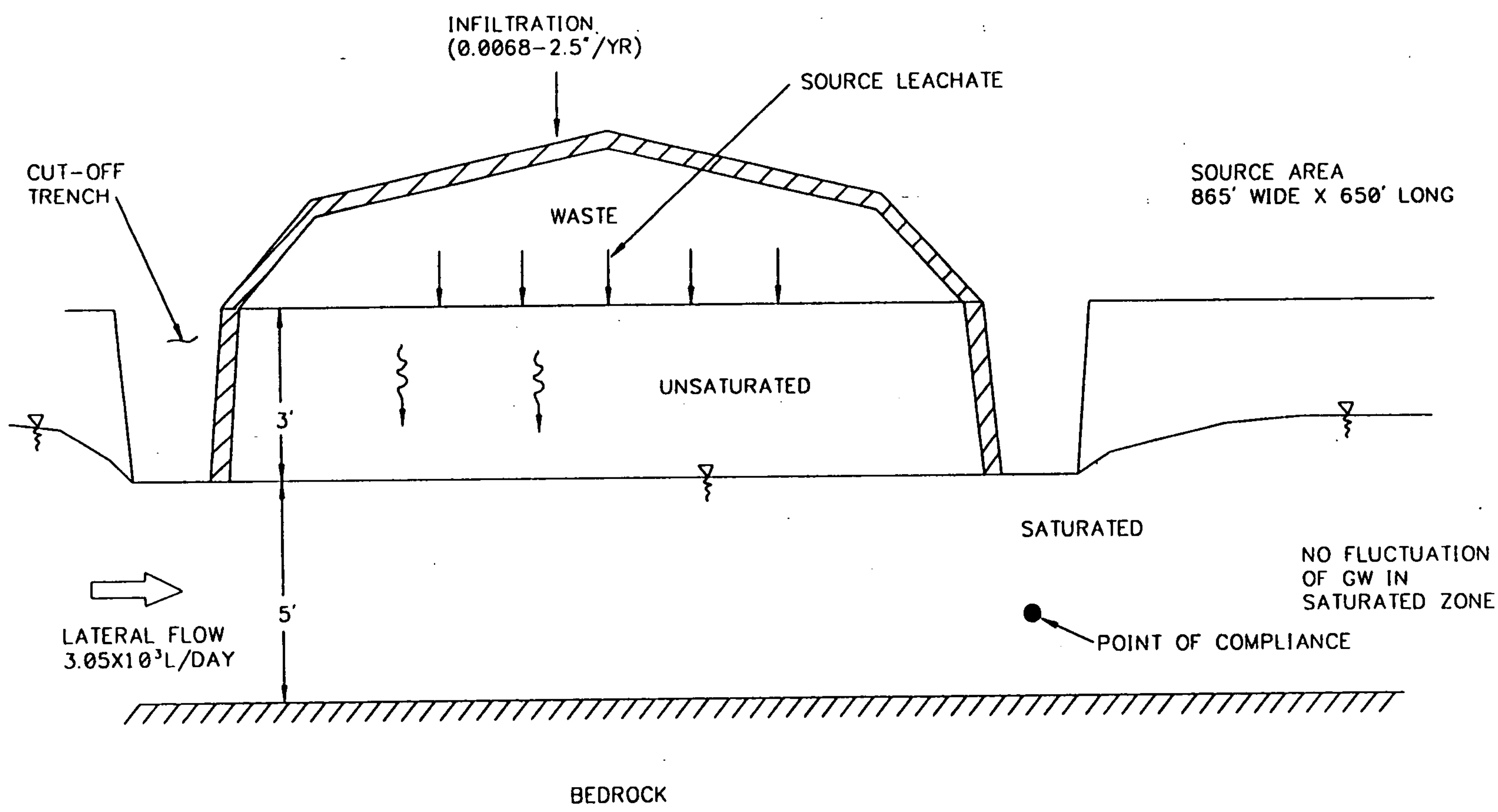


SCENARIO 1 – CONCEPTUAL MODEL
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-20

Halliburton NUS CORPORATION

ACAD: O:\DATA\CADD\3A/5\95040302.DWG 04/03/95 VB VIEW=2A

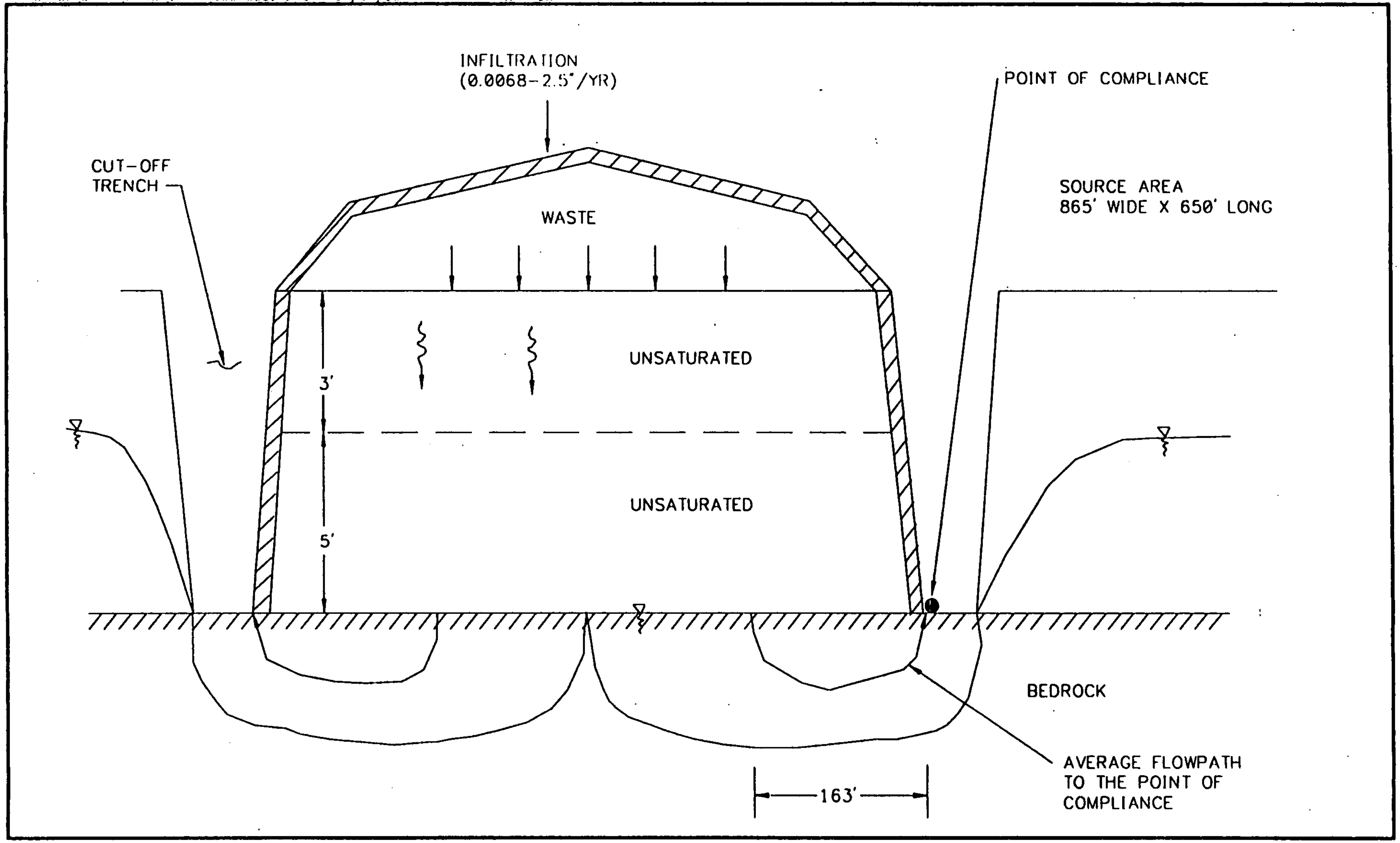


SCENARIO 2 - CONCEPTUAL MODEL
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-21

Halliburton NUS CORPORATION

ACAD: O:\DATA\CADD\3A75\95040302.DWG 04/03/95 VB VIEW=3B



SCENARIO 3 – CONCEPTUAL MODEL
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-22

Halliburton NUS CORPORATION

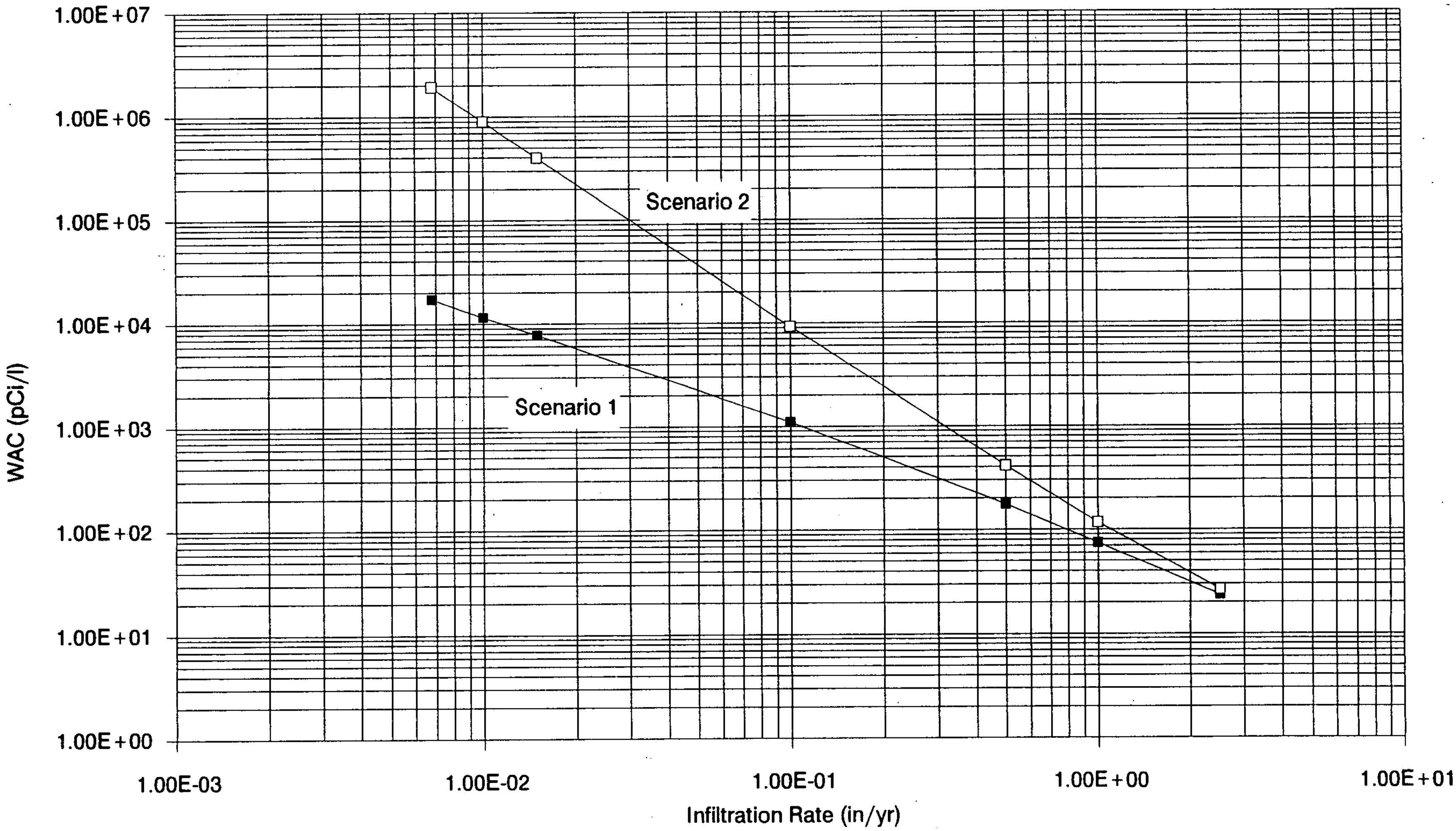


FIGURE B-23 AMERICIUM-241 WAC RESULTS

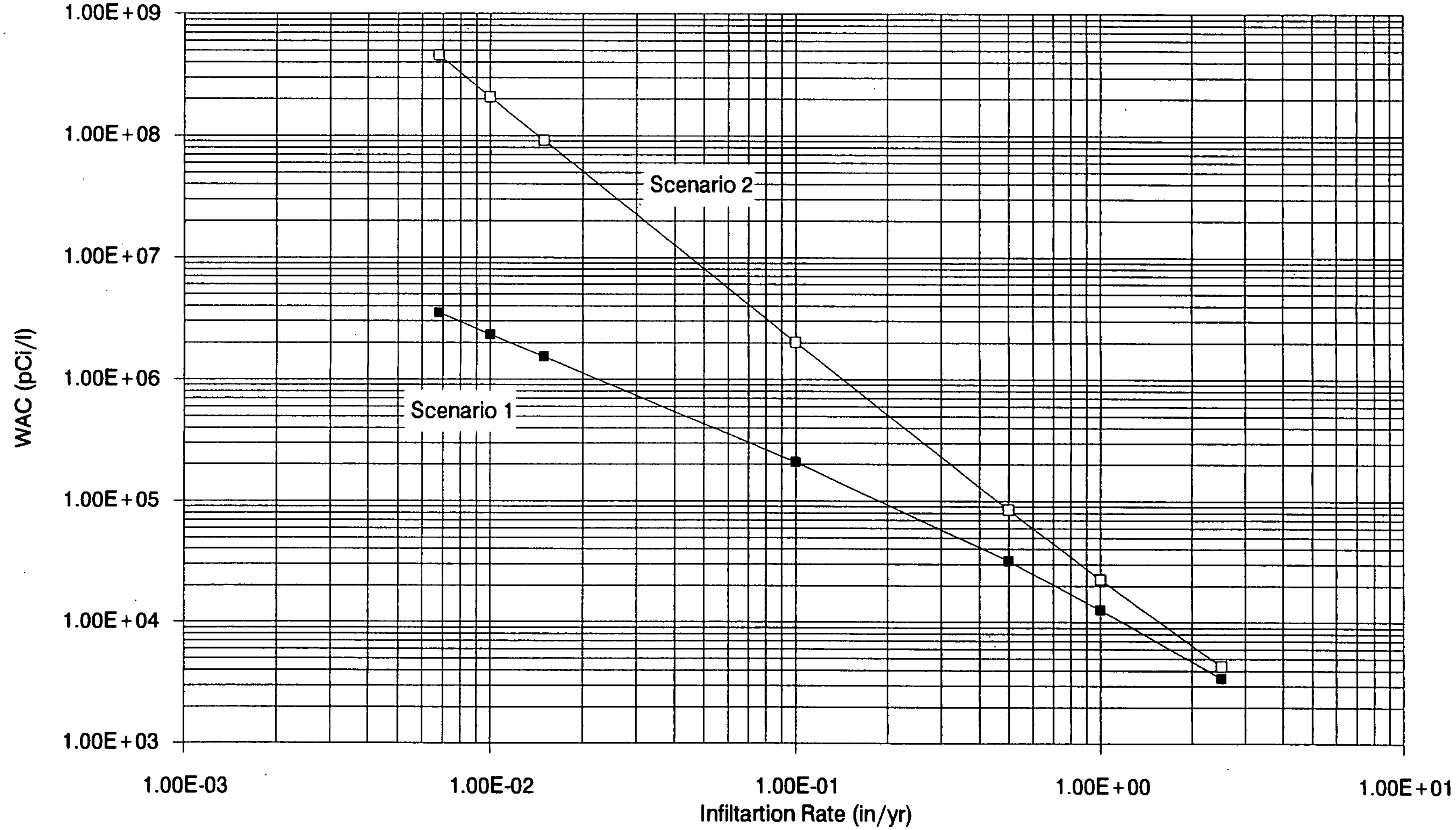


FIGURE B-24 CESIUM-134 WAC RESULTS

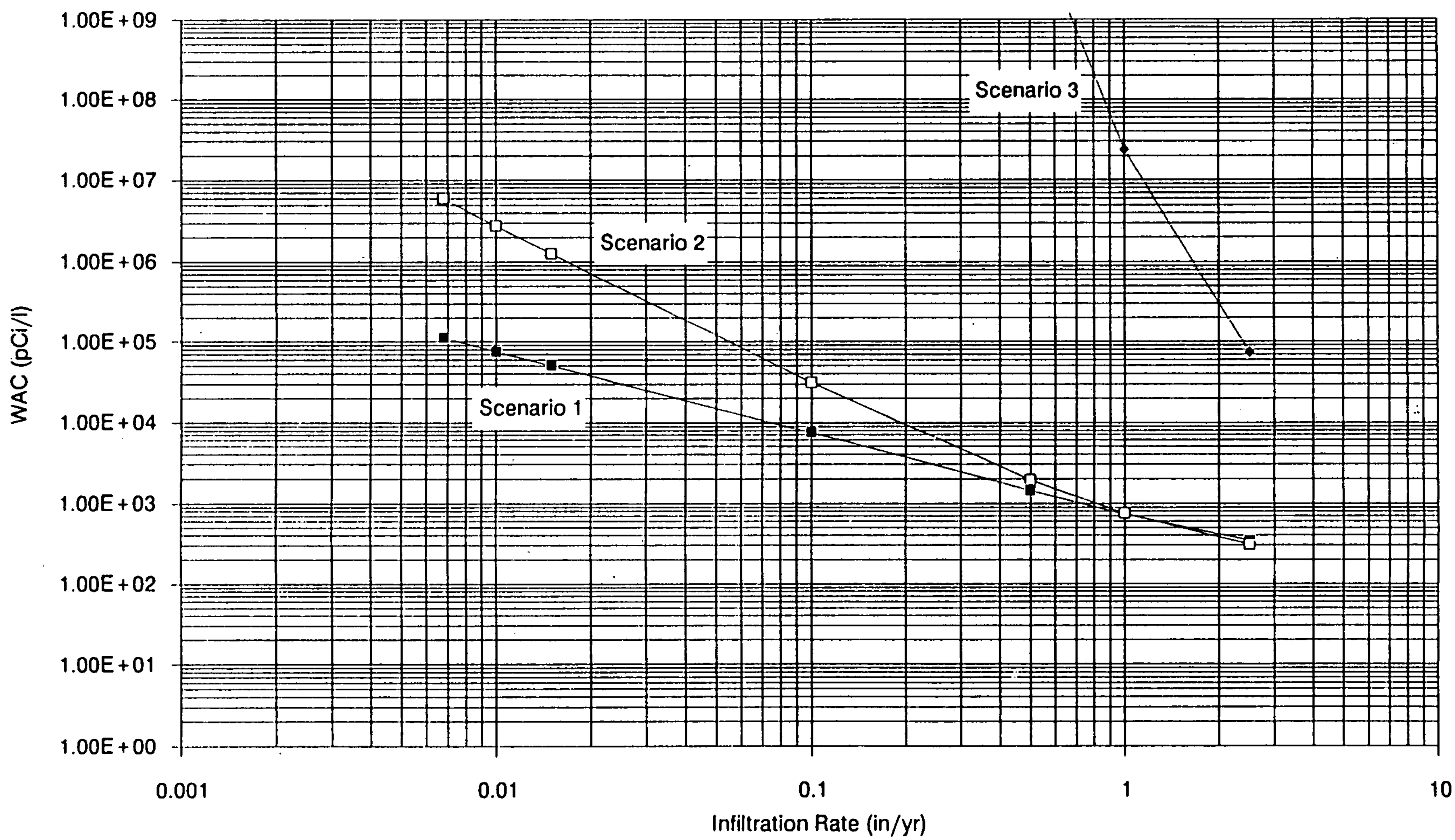


FIGURE B-25 CESIUM-137 WAC RESULTS

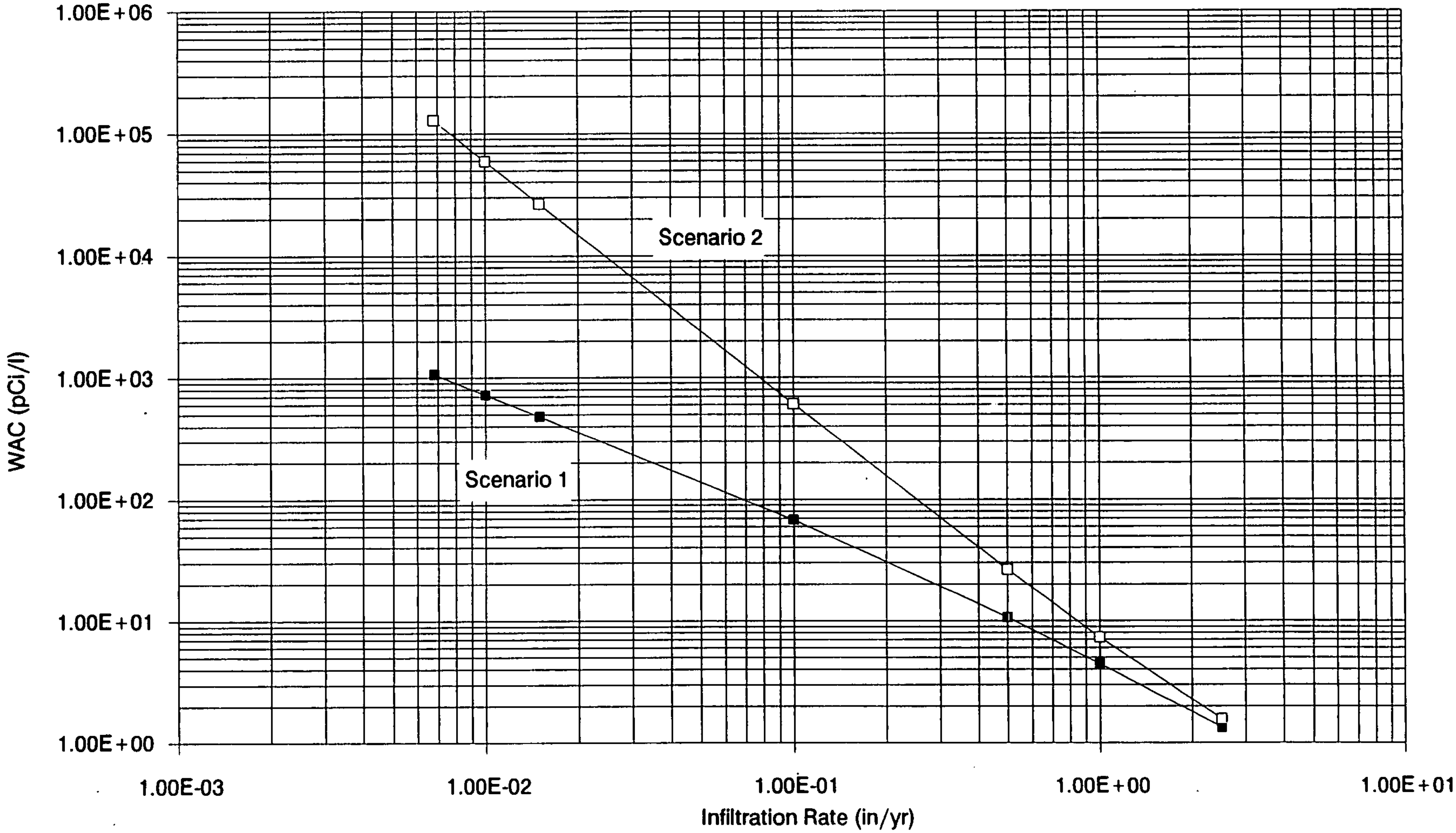


FIGURE B-26 PLUTONIUM-239/240 WAC RESULTS

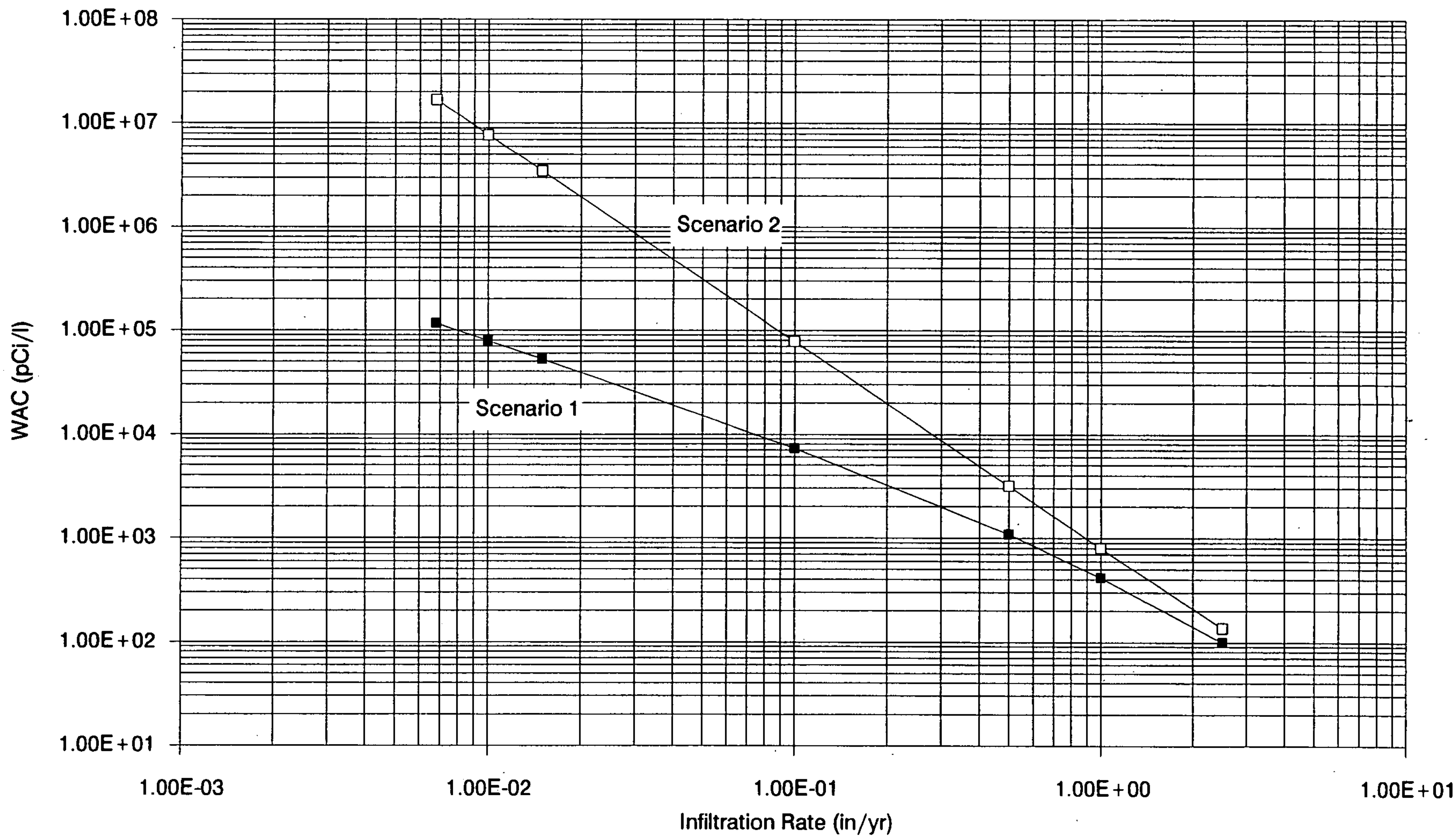


FIGURE B-27 RADIUM-226 WAC RESULTS

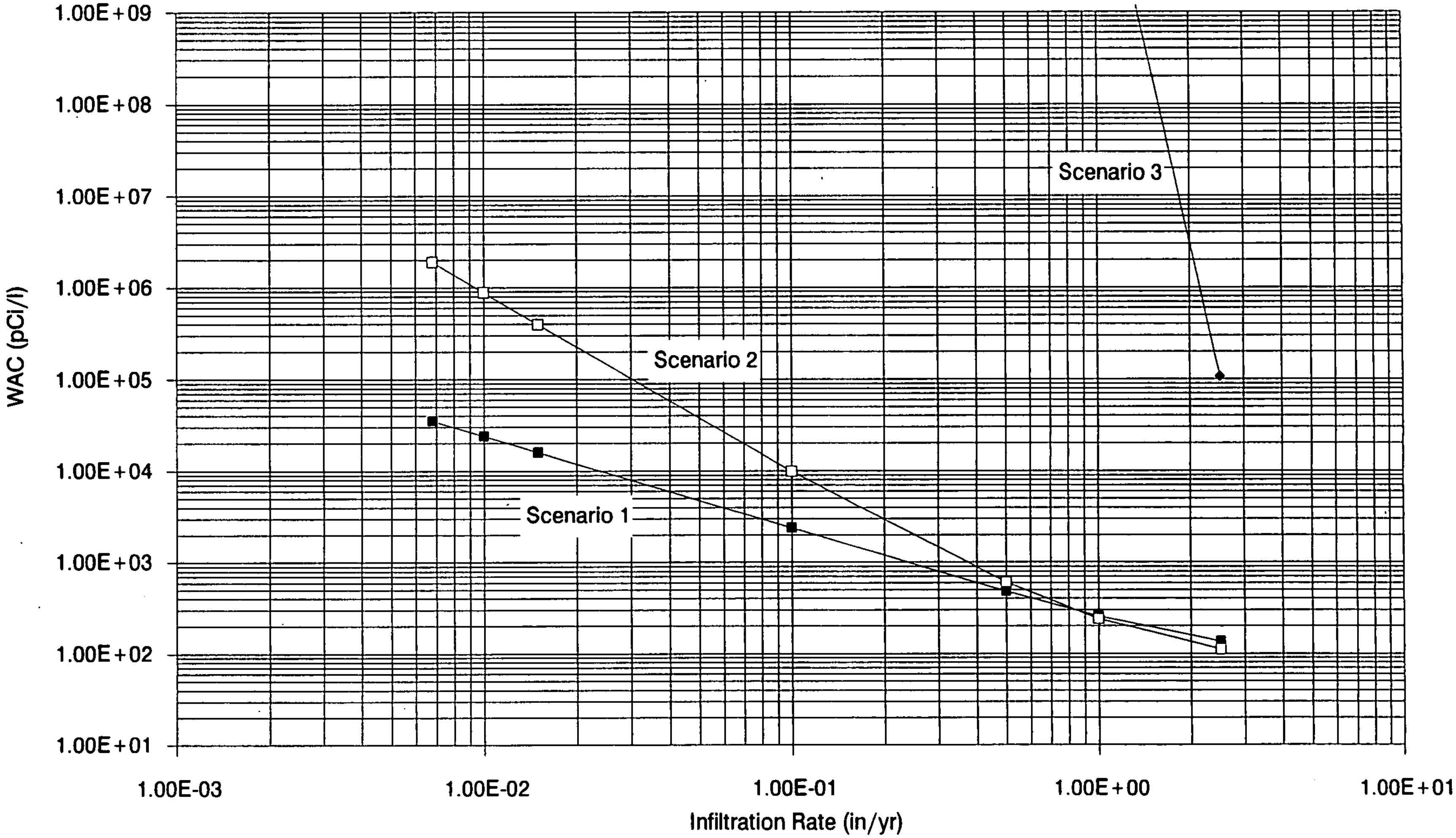


FIGURE B-28 URANIUM-233/234 WAC RESULTS

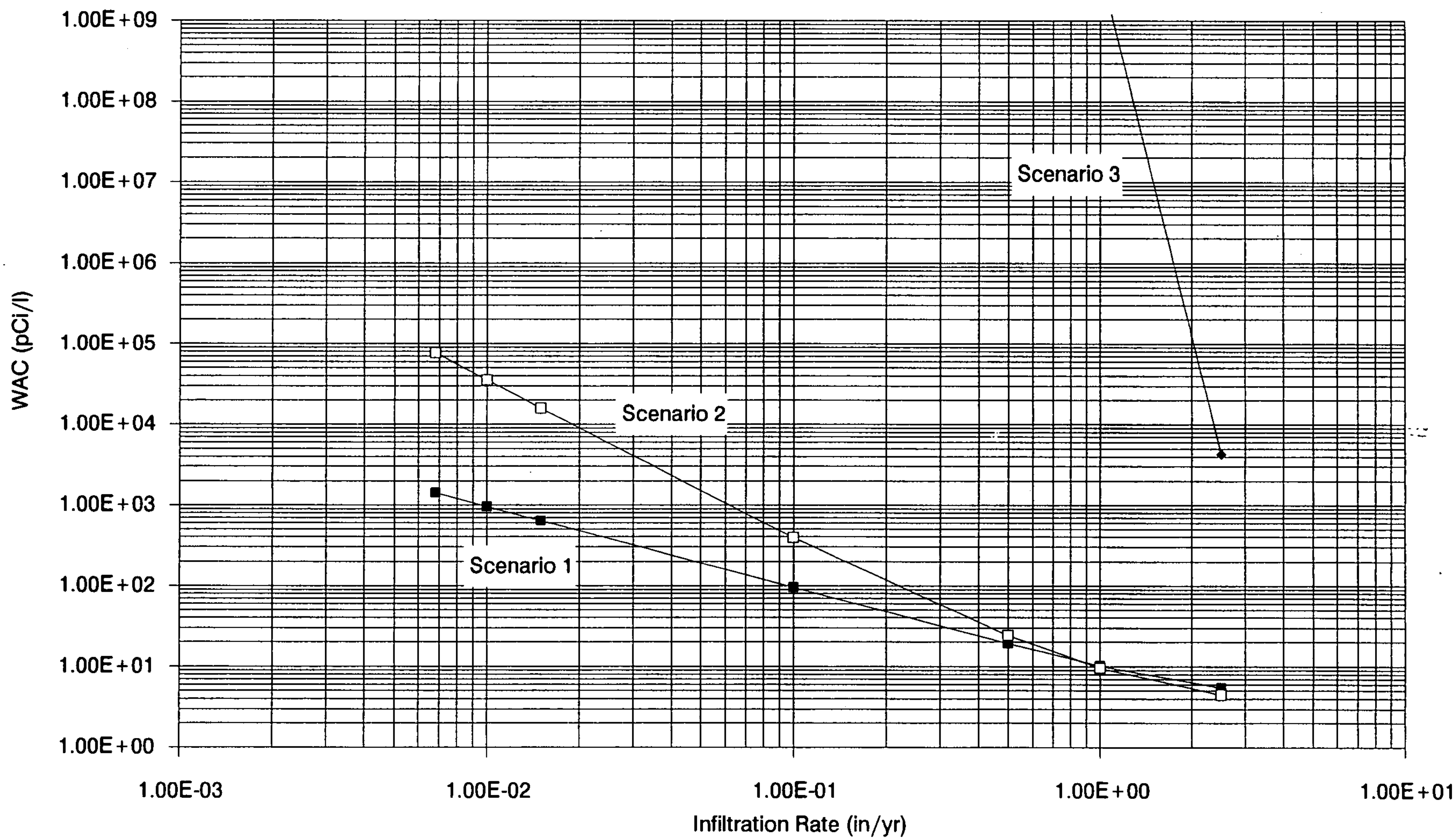


FIGURE B-29 URANIUM-235 WAC RESULTS

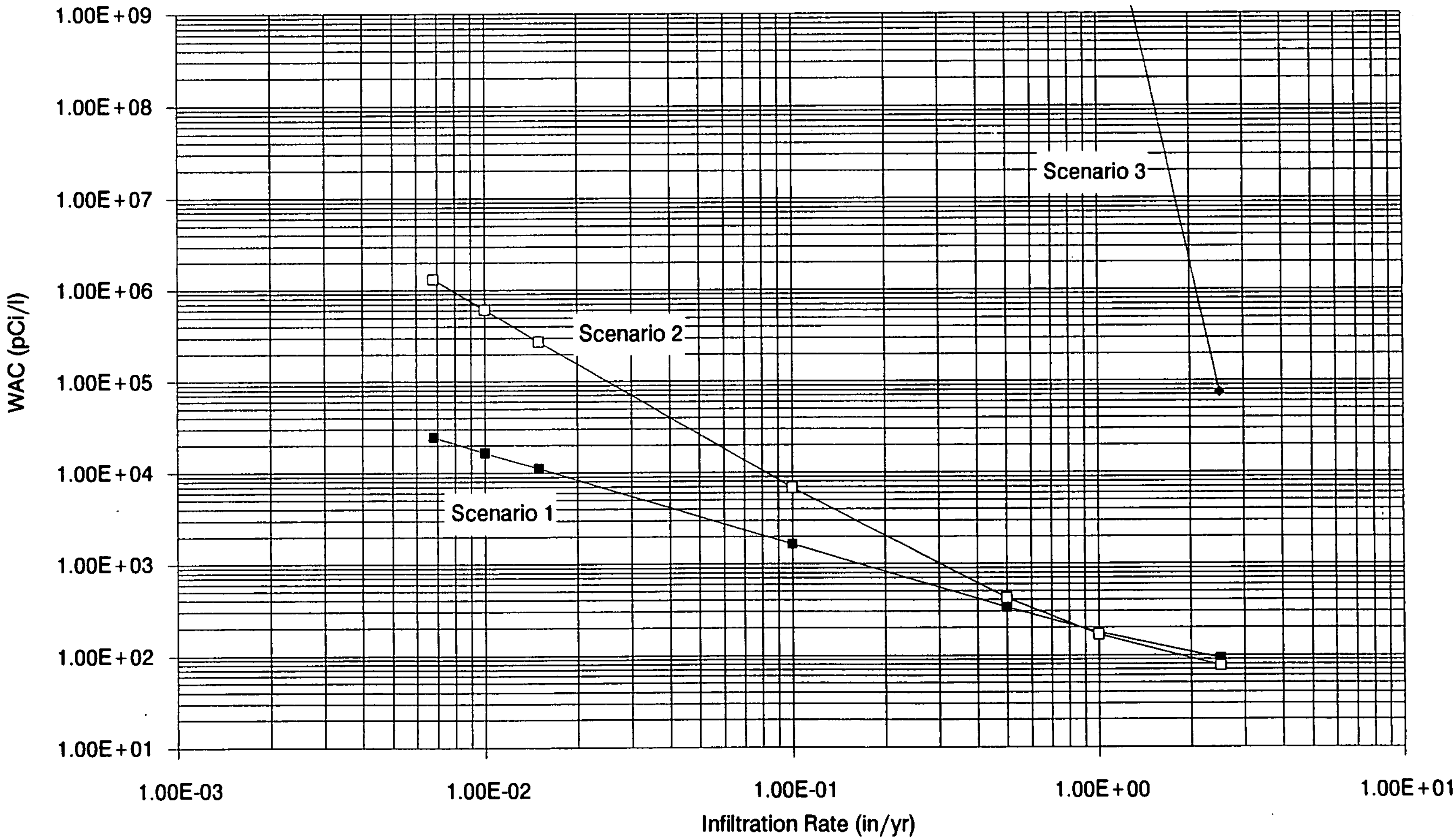


FIGURE B-30 URANIUM-238 WAC RESULTS

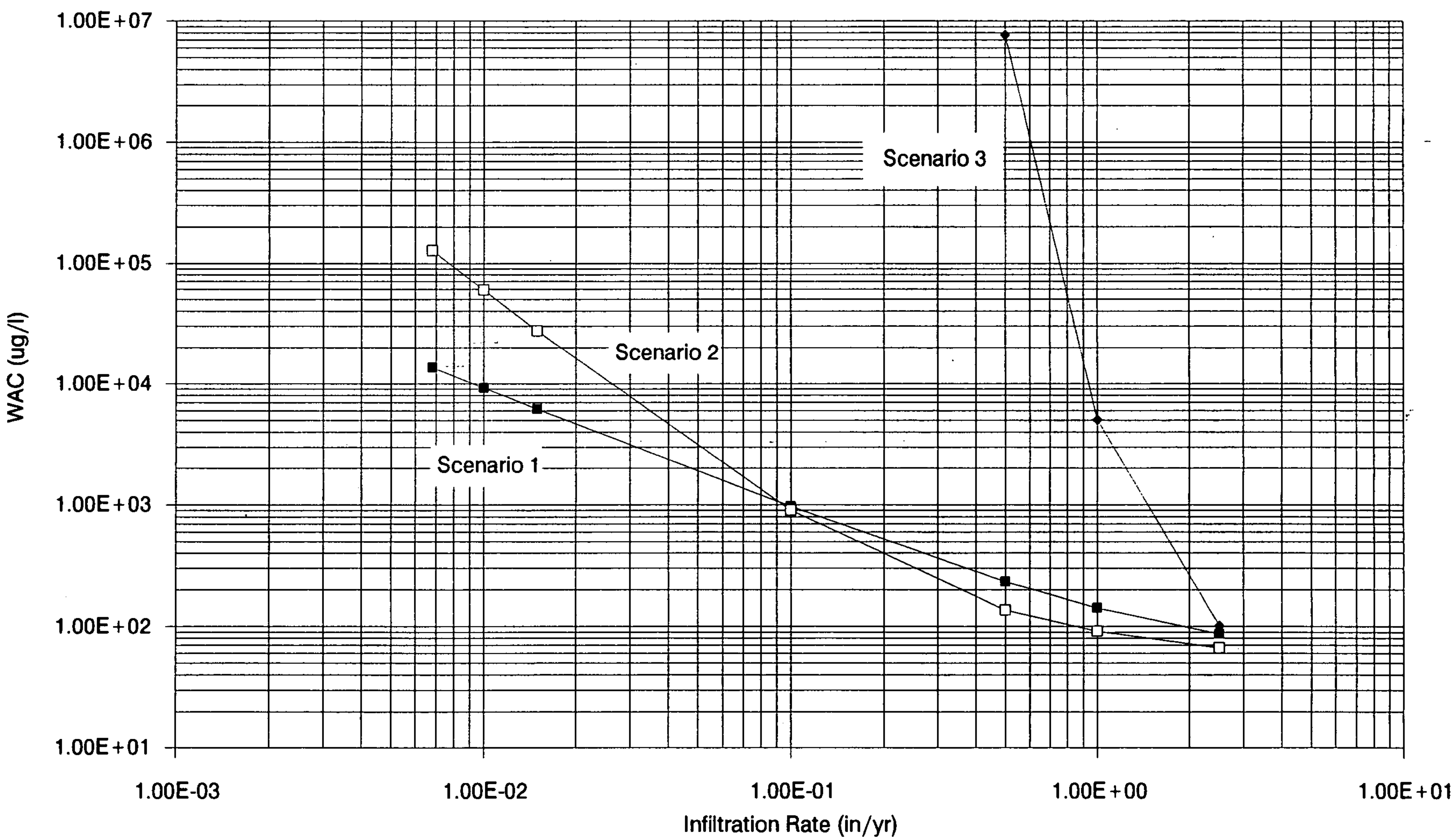


FIGURE B-31 ARSENIC WAC RESULTS

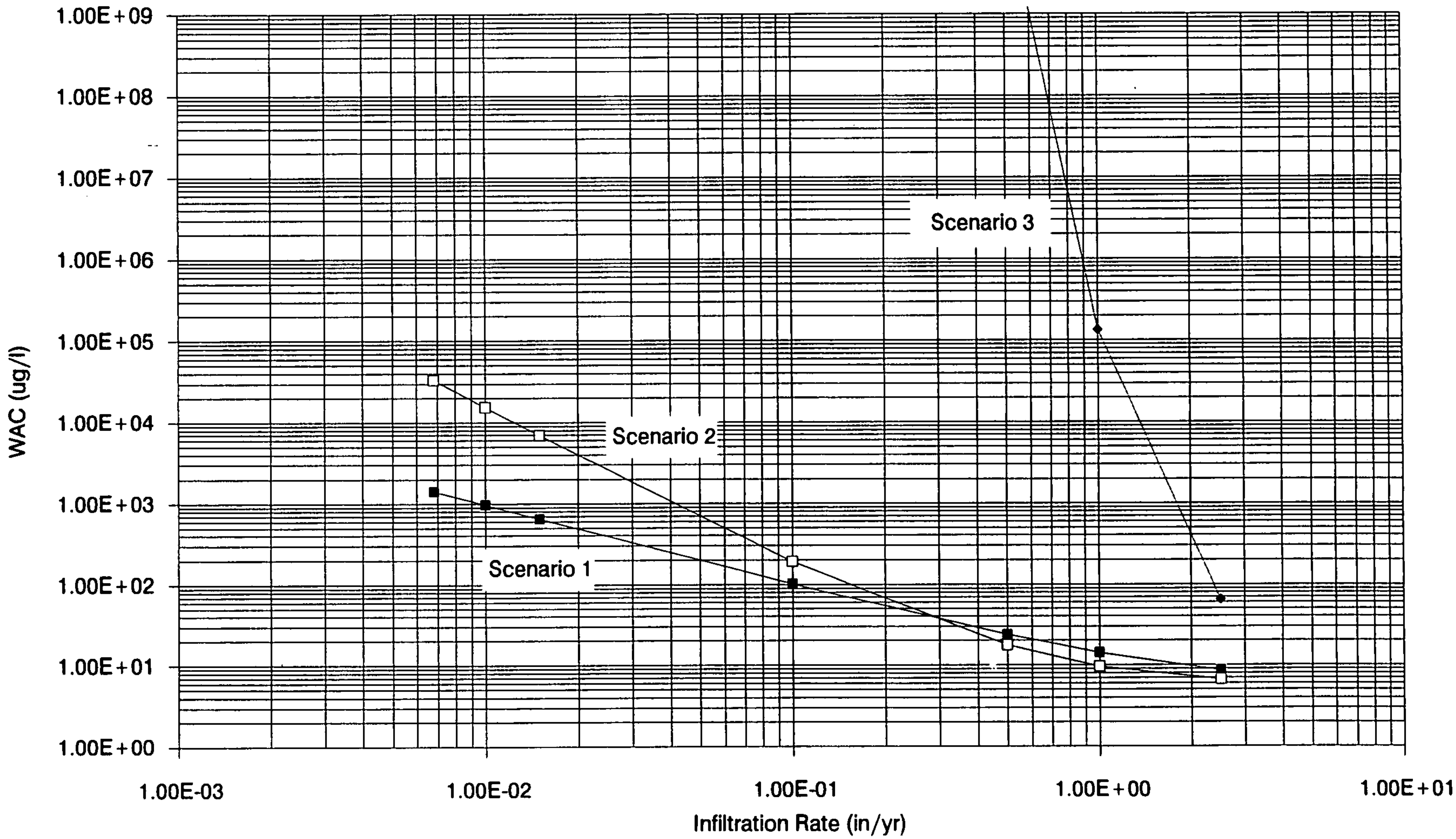


FIGURE B-32 BERYLLIUM WAC RESULTS

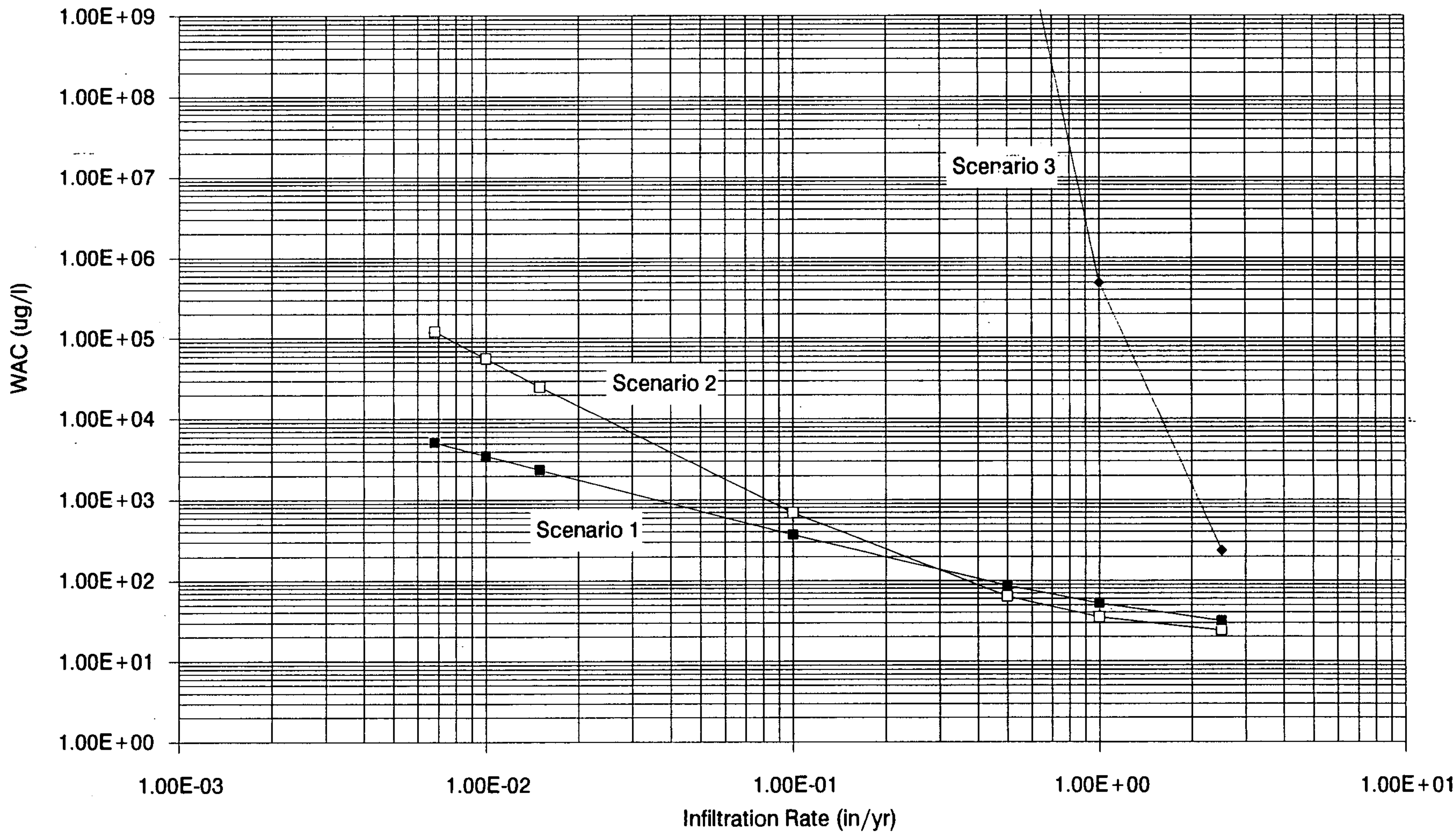


FIGURE B-33 CADMIUM WAC RESULTS

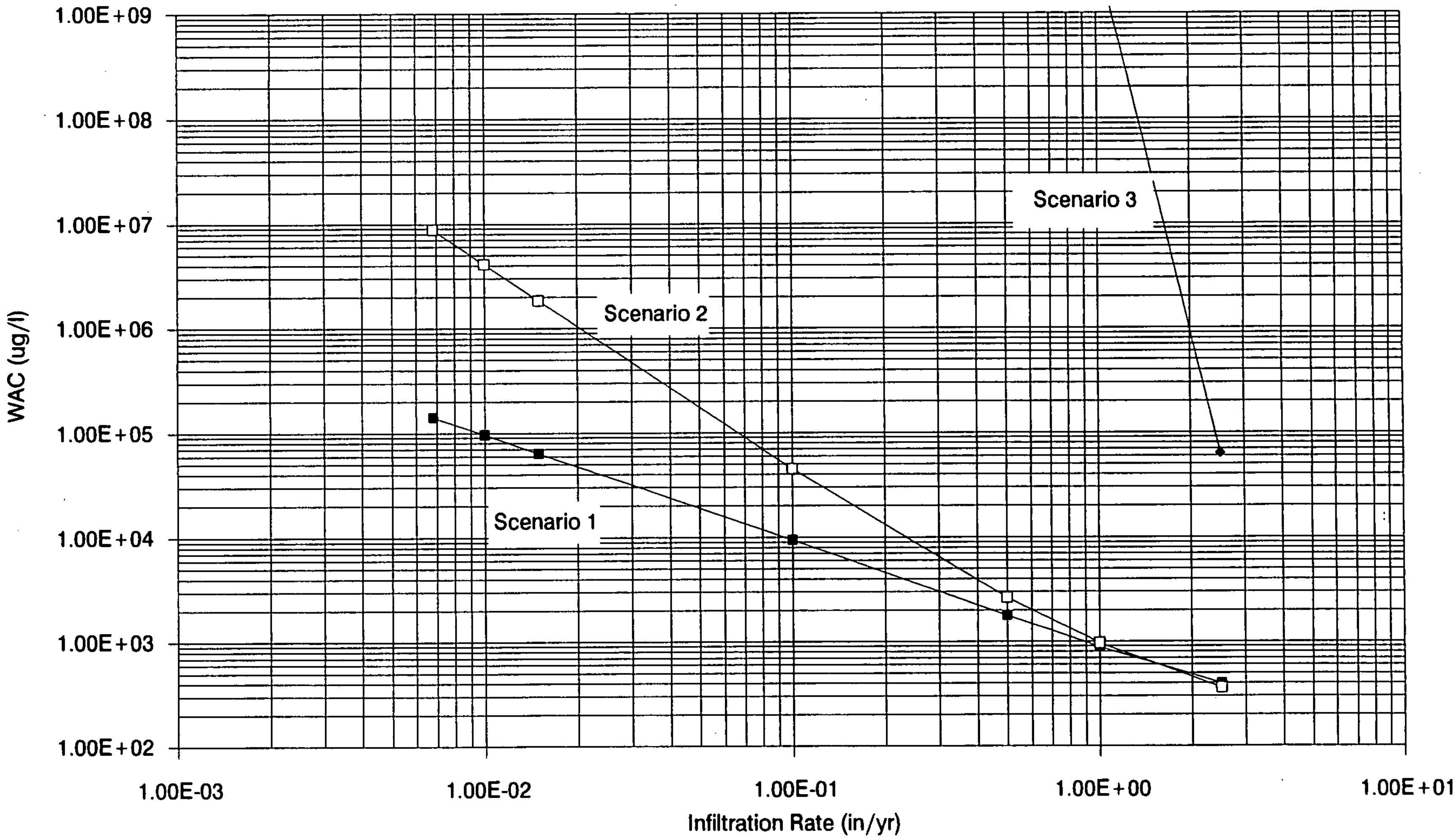


FIGURE B-34 CHROMIUM WAC RESULTS

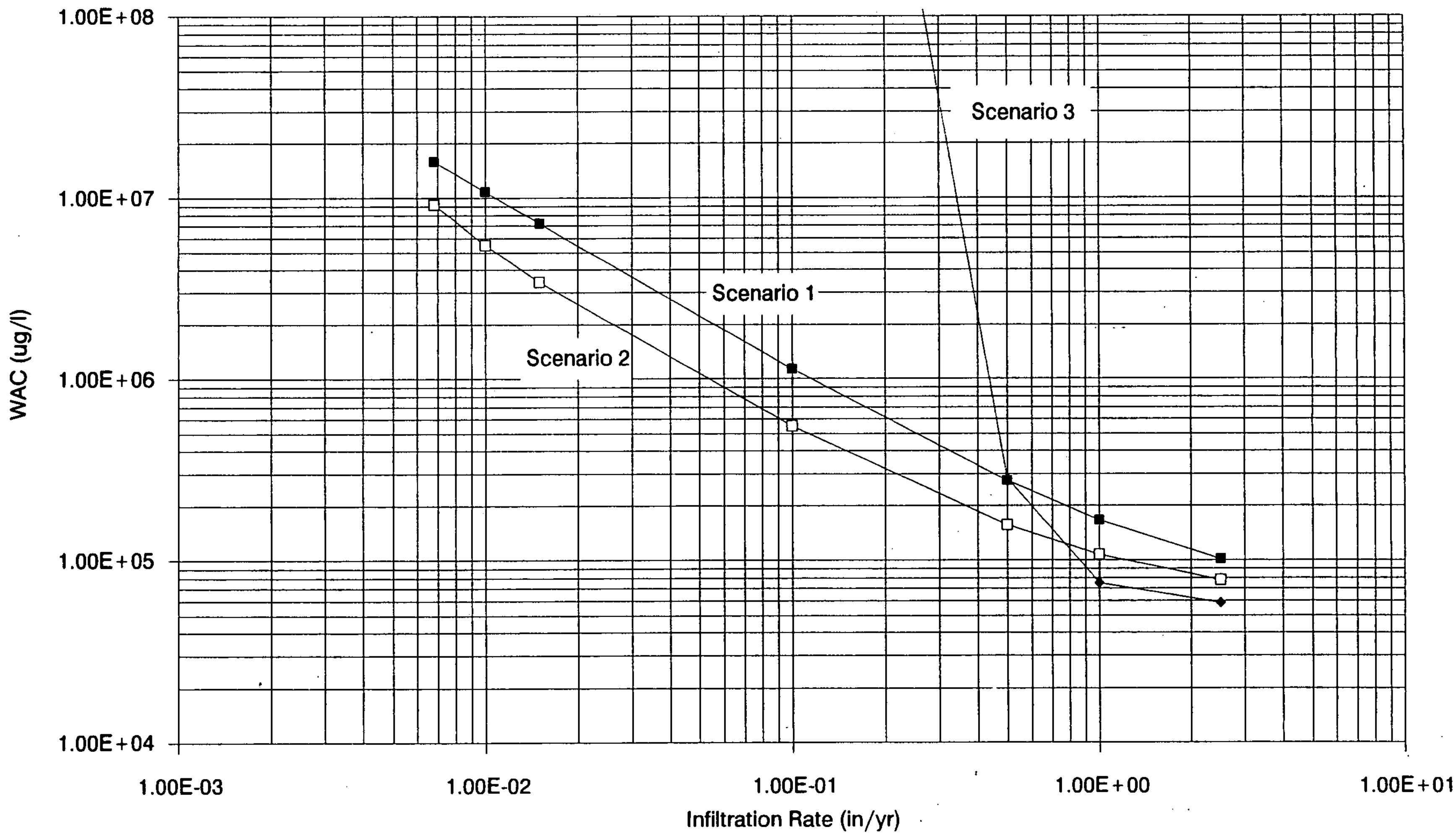


FIGURE B-35 NITRATE WAC RESULTS

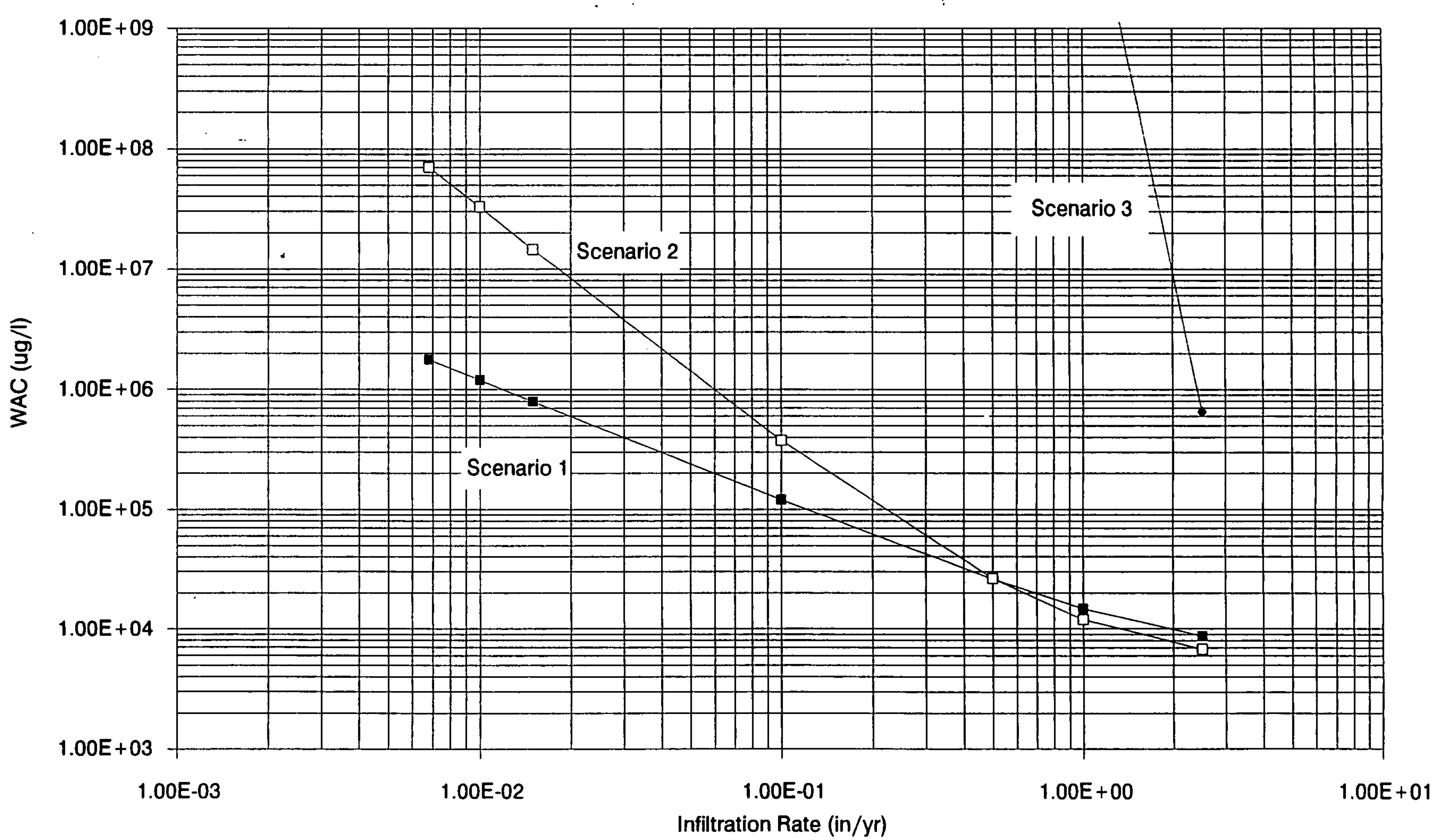


FIGURE B-36 SODIUM WAC RESULTS

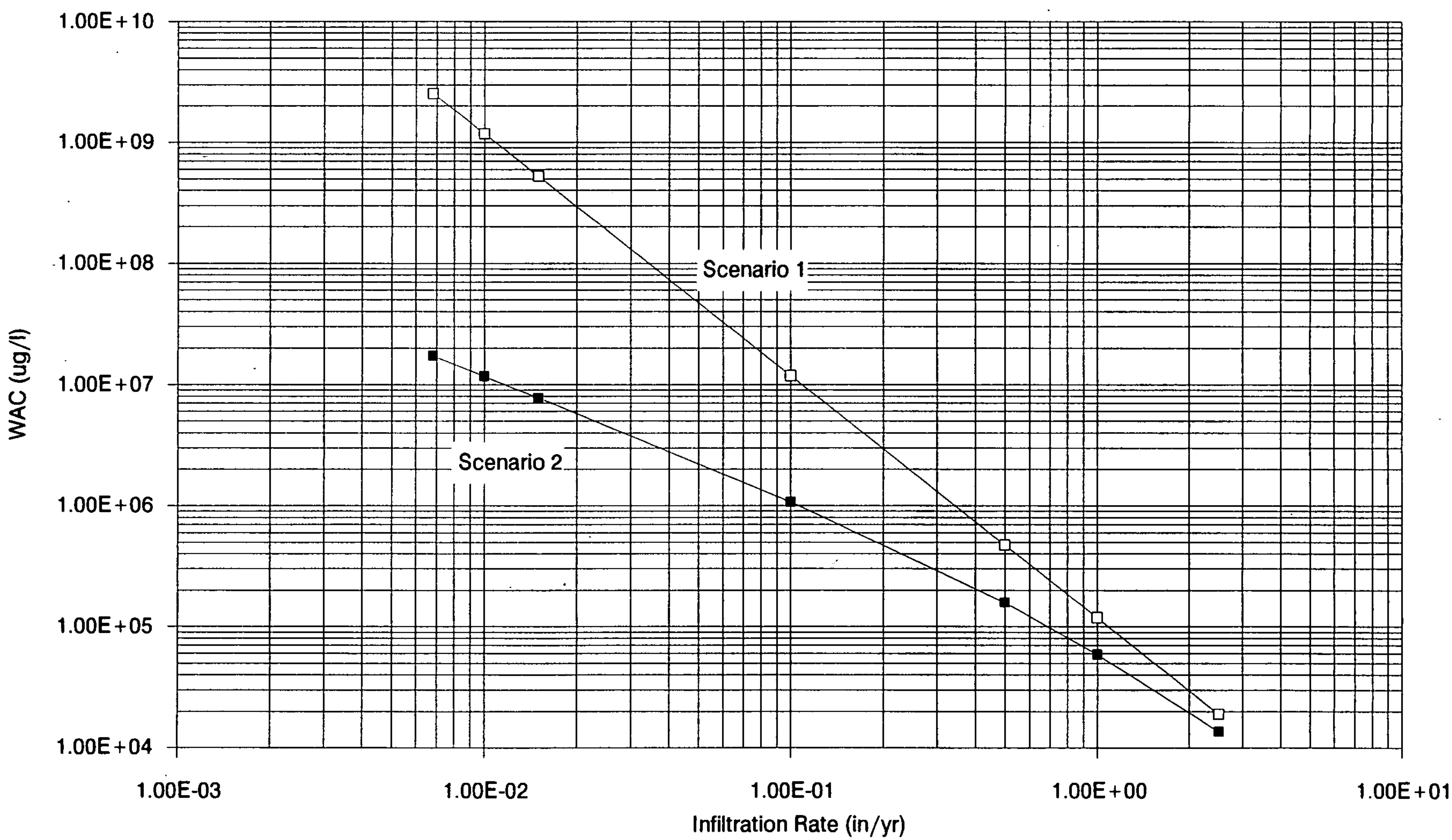


FIGURE B-37 AROCHLOR-1254 WAC RESULTS

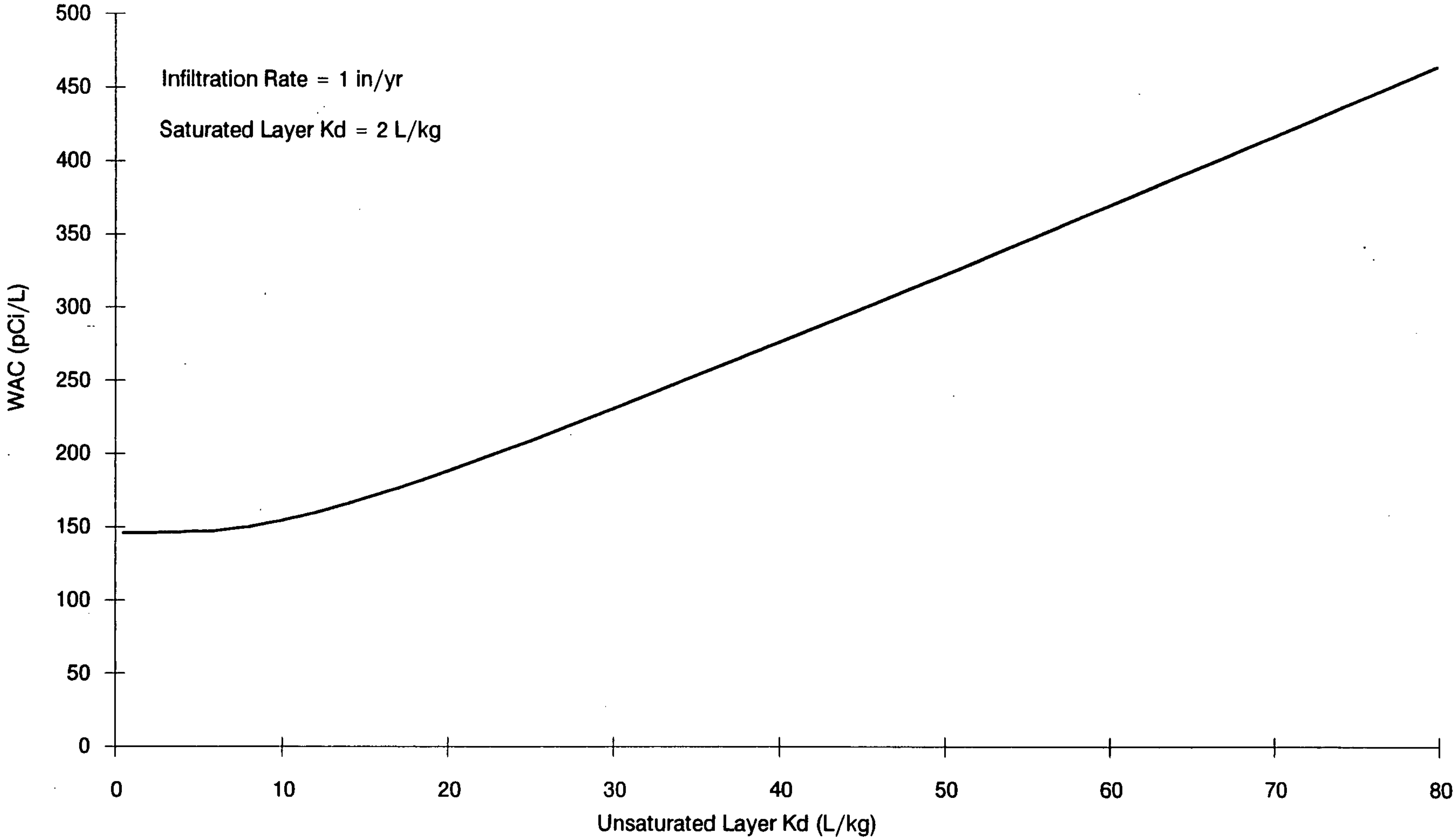


FIGURE B-38 SENSITIVITY OF URANIUM-238 WAC TO UNSATURATED LAYER Kd

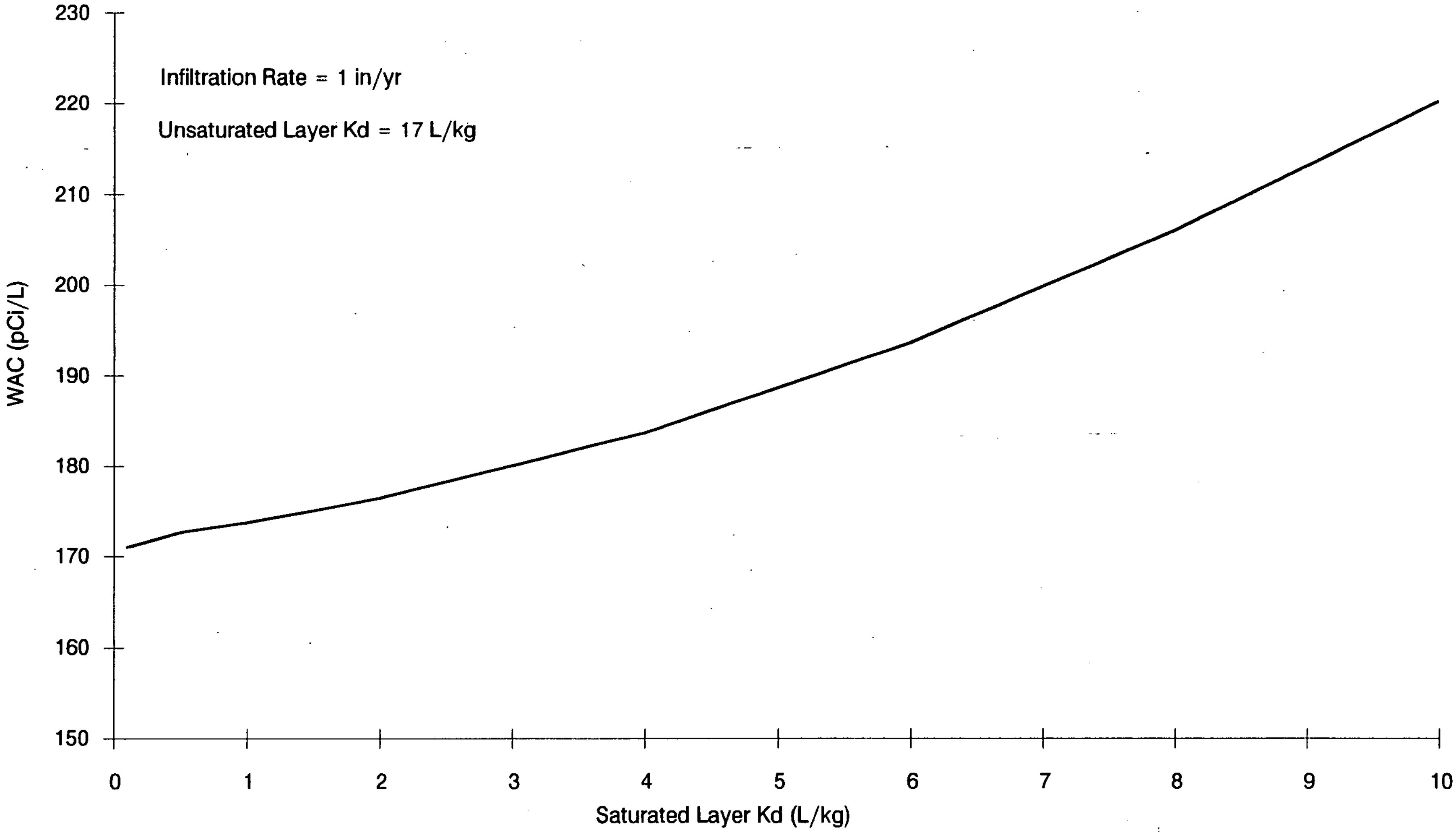


FIGURE B-39 SENSITIVITY OF URANIUM-238 WAC TO SATURATED LAYER Kd

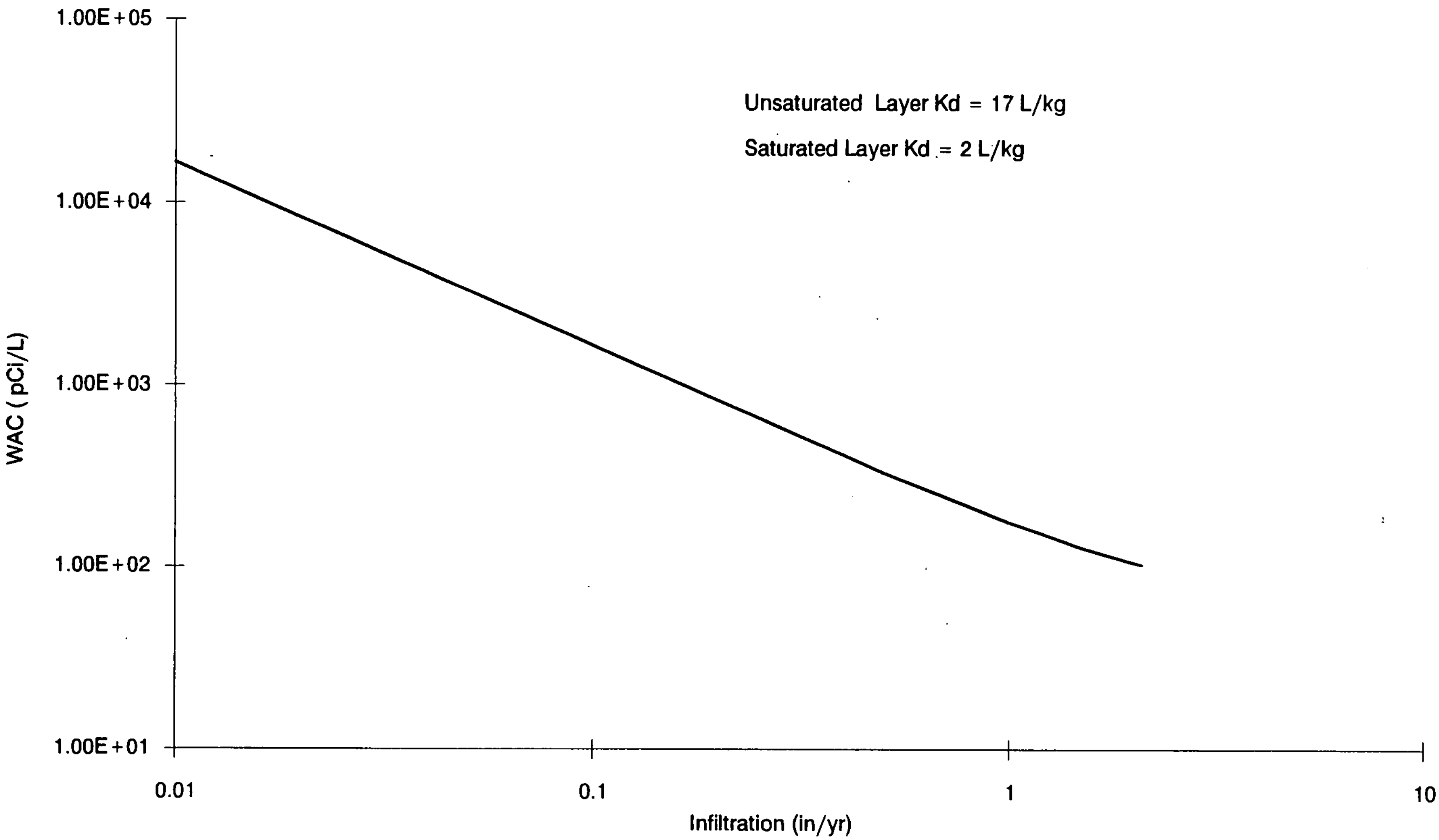


FIGURE B-40 SENSITIVITY OF URANIUM-238 WAC TO INFILTRATION RATE

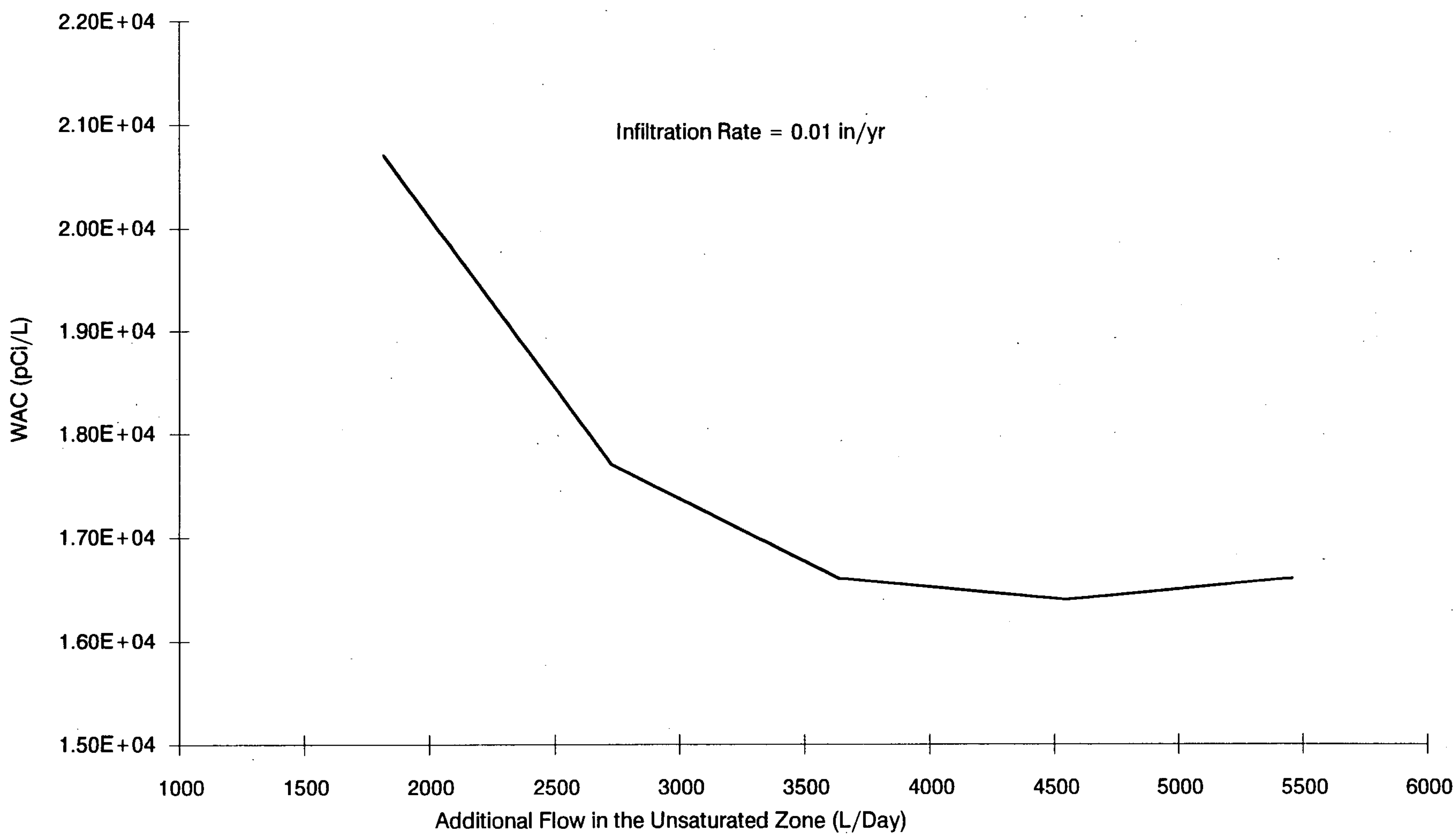


FIGURE B-41 SENSITIVITY OF URANIUM-238 WAC TO ADDITIONAL FLOW IN THE UNSATURATED ZONE (LOW INFILTRATION)

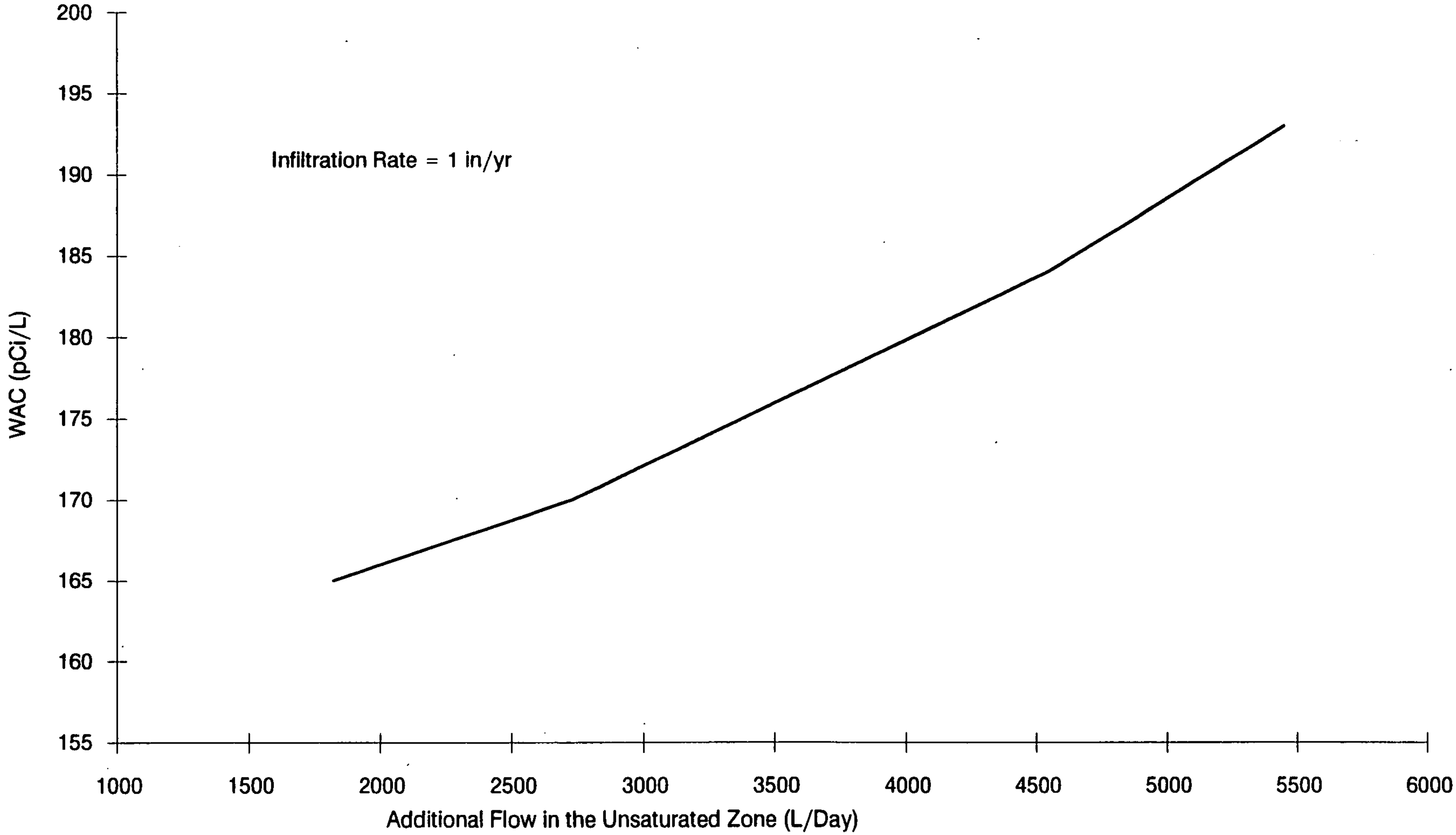
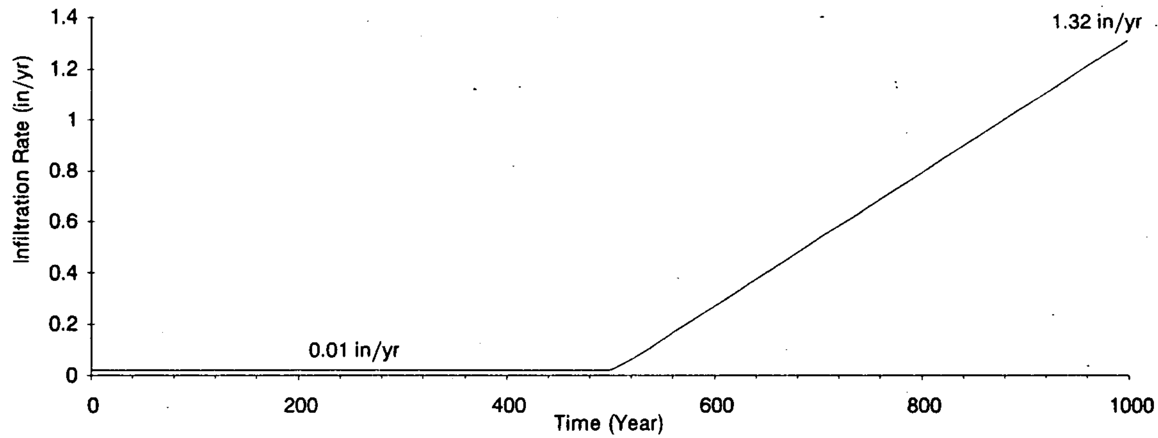
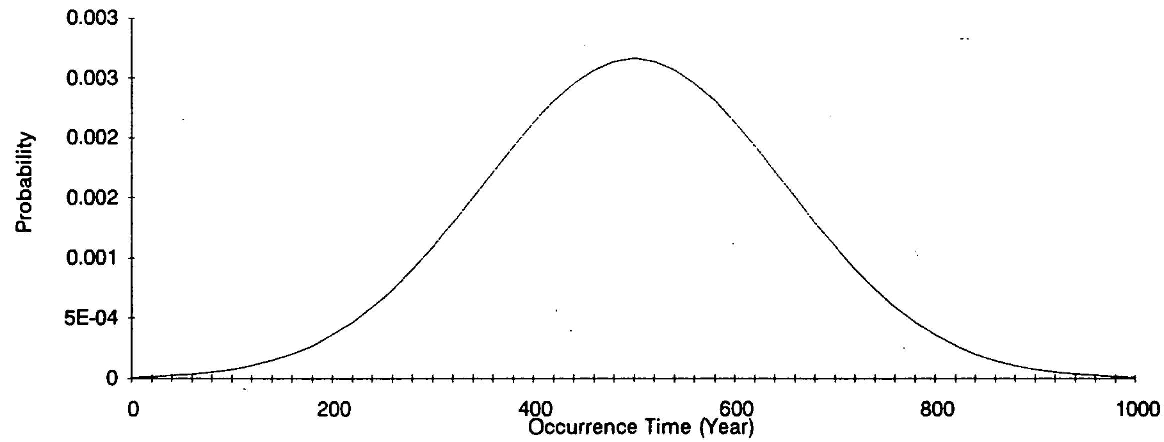


FIGURE B-42 SENSITIVITY OF URANIUM-238 WAC TO ADDITIONAL FLOW IN THE UNSATURATED ZONE (HIGHER INFILTRATION)

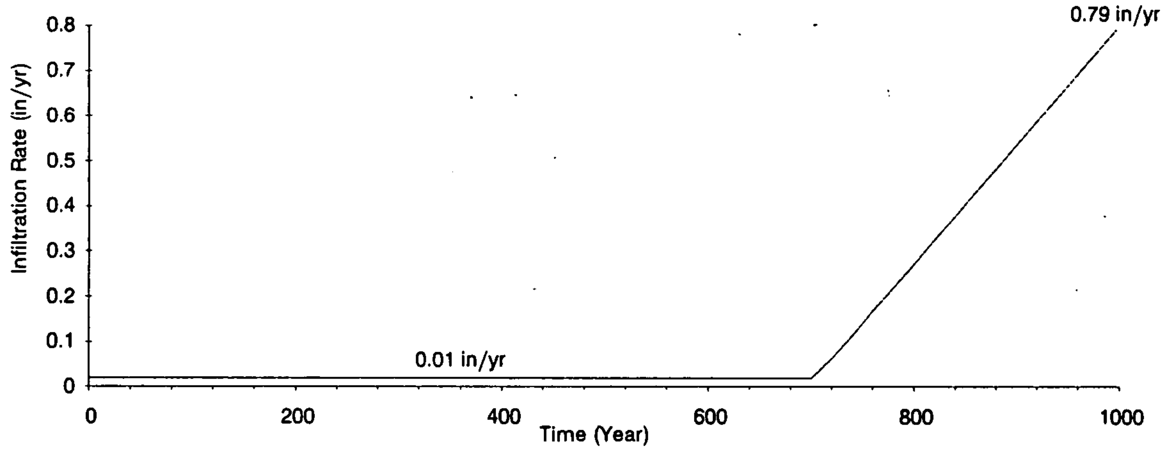


Pattern of Infiltration Rate (Case 1)

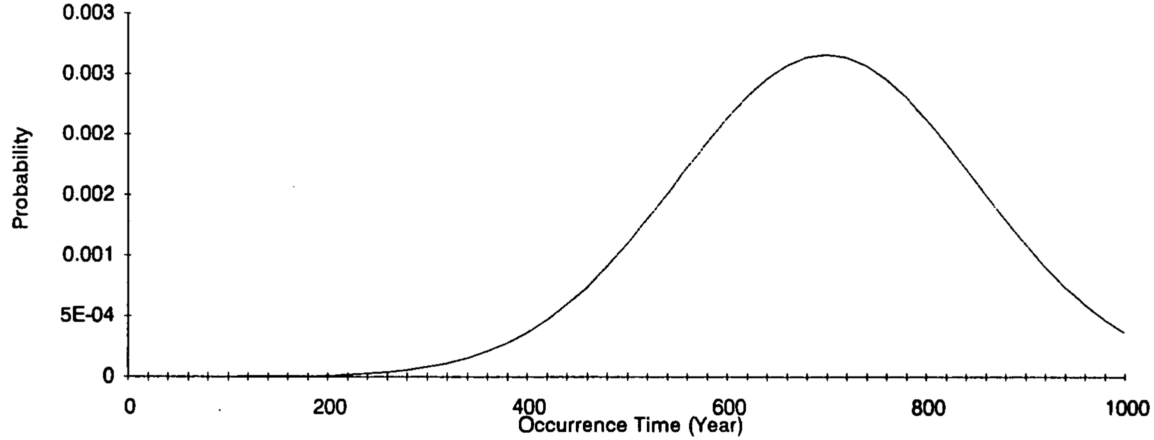


Probability Distribution of Initiation of Degradation of Impervious Liner (Case 1)

FIGURE B-43 INFILTRATION PATTERN FOR PROBABILISTIC SENSITIVITY CASE 1

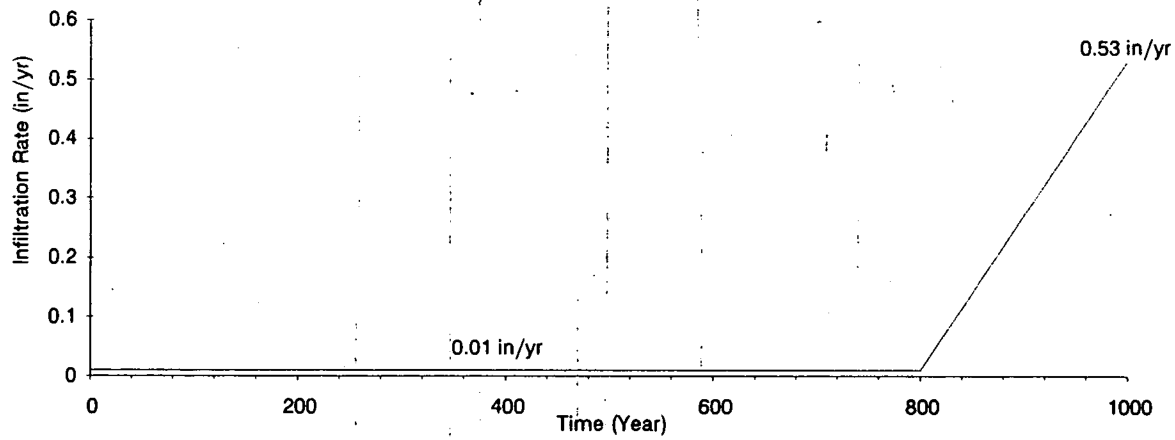


Pattern of Infiltration Rate (Case 2)

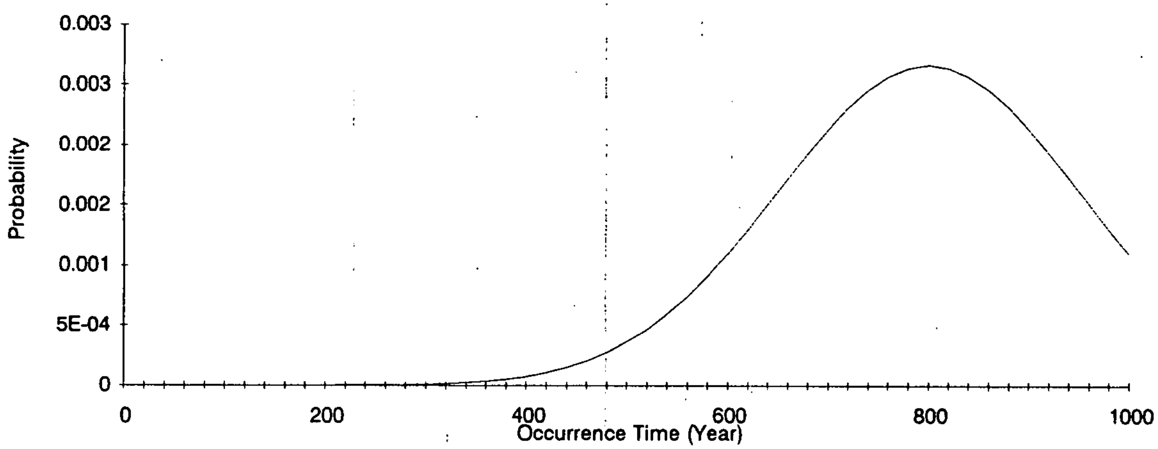


Probability Distribution of Initiation of Degradation of Impervious Liner (Case 2)

FIGURE B-44 INFILTRATION PATTERN FOR PROBABILISTIC SENSITIVITY CASE 2



Pattern of Infiltration Rate (Case 3)



Probability Distribution of Initiation of Degradation of Impervious Liner (Case 3)

FIGURE B-45 INFILTRATION PATTERN FOR PROBABILISTIC SENSITIVITY CASE 3

Forecast: Max. Saturated Layer Conc. **Cell: L79**

Summary:

Display Range is from 0.00E+0 to 1.10E+2 pCi/L
Entire Range is from 2.52E-1 to 1.01E+2 pCi/L
After 1,000 Trials, the Std. Error of the Mean is 8.05E-1

Statistics:	Value
Trials	1000
Mean	4.01E+01
Median (approx.)	3.75E+01
Mode (approx.)	1.19E+01
Standard Deviation	2.54E+01
Variance	6.47E+02
Skewness	0.31
Kurtosis	2.01
Coeff. of Variability	0.63
Range Minimum	2.52E-01
Range Maximum	1.01E+02
Range Width	1.01E+02
Mean Std. Error	8.05E-01

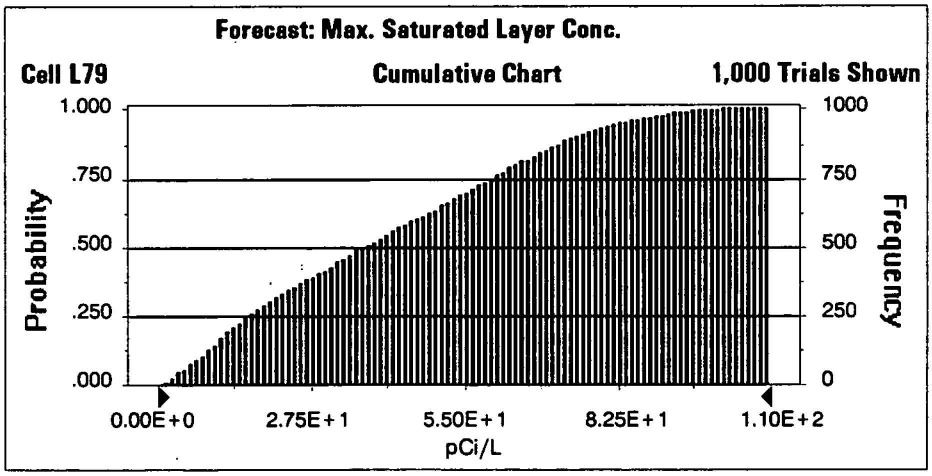


FIGURE B-46a SAMPLE MONTE CARLO SIMULATION OUTPUT

Forecast: Max. Saturated Layer Conc. (cont'd) **Cell: L79**

Percentiles:

Percentile	pCi/L (approx.)
0%	2.52E-01
10%	8.34E+00
20%	1.38E+01
30%	2.08E+01
40%	2.92E+01
50%	3.75E+01
60%	4.69E+01
70%	5.62E+01
80%	6.46E+01
90%	7.58E+01
100%	1.01E+02

End of Forecast

FIGURE B-46b SAMPLE MONTE CARLO SIMULATION OUTPUT

Forecast: Conc. in Saturated Layer at 200 yr **Cell: L37**

Summary:

Display Range is from 0.00E+0 to 1.20E+0 pCi/L
Entire Range is from 2.32E-3 to 6.20E+0 pCi/L
After 1,000 Trials, the Std. Error of the Mean is 1.05E-2

Statistics:	Value
Trials	1000
Mean	2.92E-01
Median (approx.)	2.02E-01
Mode (approx.)	3.33E-02
Standard Deviation	3.33E-01
Variance	1.11E-01
Skewness	7.19
Kurtosis	111.14
Coeff. of Variability	1.14
Range Minimum	2.32E-03
Range Maximum	6.20E+00
Range Width	6.20E+00
Mean Std. Error	1.05E-02

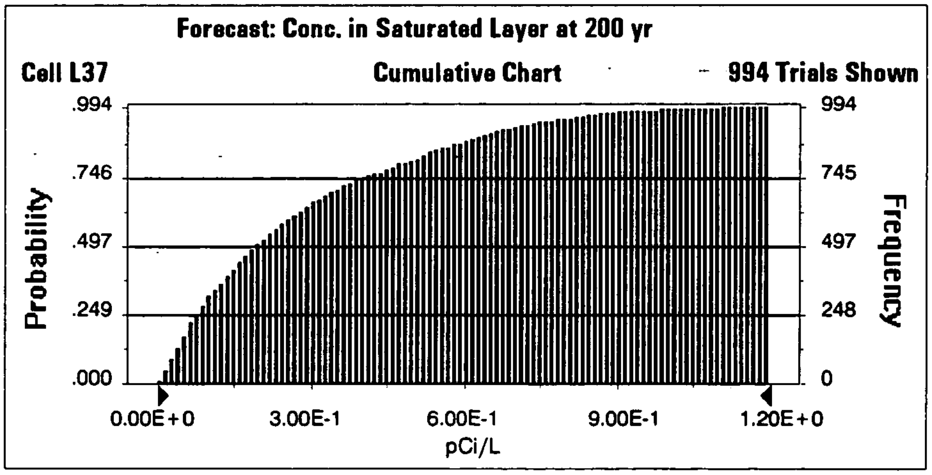


FIGURE B-46c SAMPLE MONTE CARLO SIMULATION OUTPUT

Forecast: Conc. in Saturated Layer at 200 yr (cont'd) **Cell: L37**

Percentiles:

Percentile	pCi/L (approx.)
0%	2.32E-03
10%	3.95E-02
20%	6.80E-02
30%	1.02E-01
40%	1.51E-01
50%	2.02E-01
60%	2.70E-01
70%	3.62E-01
80%	4.98E-01
90%	6.57E-01
100%	6.20E+00

End of Forecast

FIGURE B-46d SAMPLE MONTE CARLO SIMULATION OUTPUT

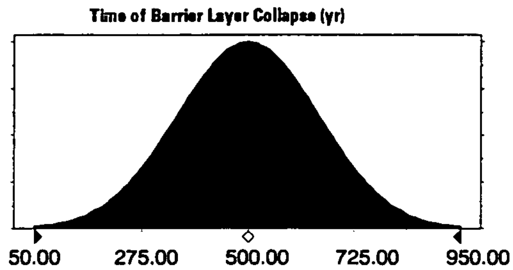
Assumptions

Assumption: Time of Barrier Layer Collapse (yr) **Cell: D18**

Normal distribution with parameters:

Mean	500.00
Standard Dev.	150.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 497.03



Assumption: Unsaturated Layer Kd (L/KG): **Cell: F16**

Lognormal distribution with parameters:

Mean	17.00
Standard Dev.	34.00

Selected range is from 0.00 to +Infinity
Mean value in simulation was 17.36

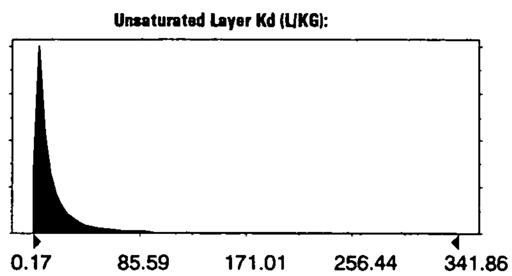


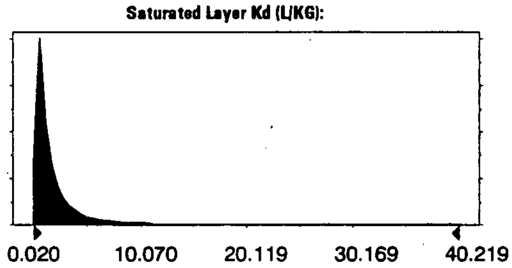
FIGURE B-46e SAMPLE MONTE CARLO SIMULATION OUTPUT

Assumption: Saturated Layer Kd (L/KG): **Cell: I16**

Lognormal distribution with parameters:

Mean	2.000
Standard Dev.	4.000

Selected range is from 0.000 to +Infinity
Mean value in simulation was 2.277

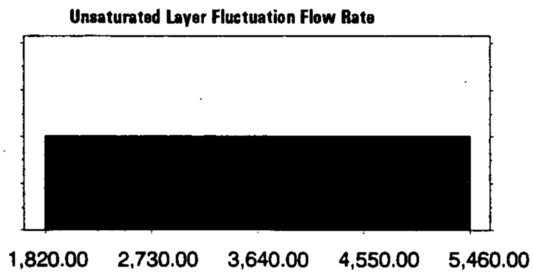


Assumption: Unsaturated Layer Fluctuation Flow Rate **Cell: F21**

Uniform distribution with parameters:

Minimum	1,820.00
Maximum	5,460.00

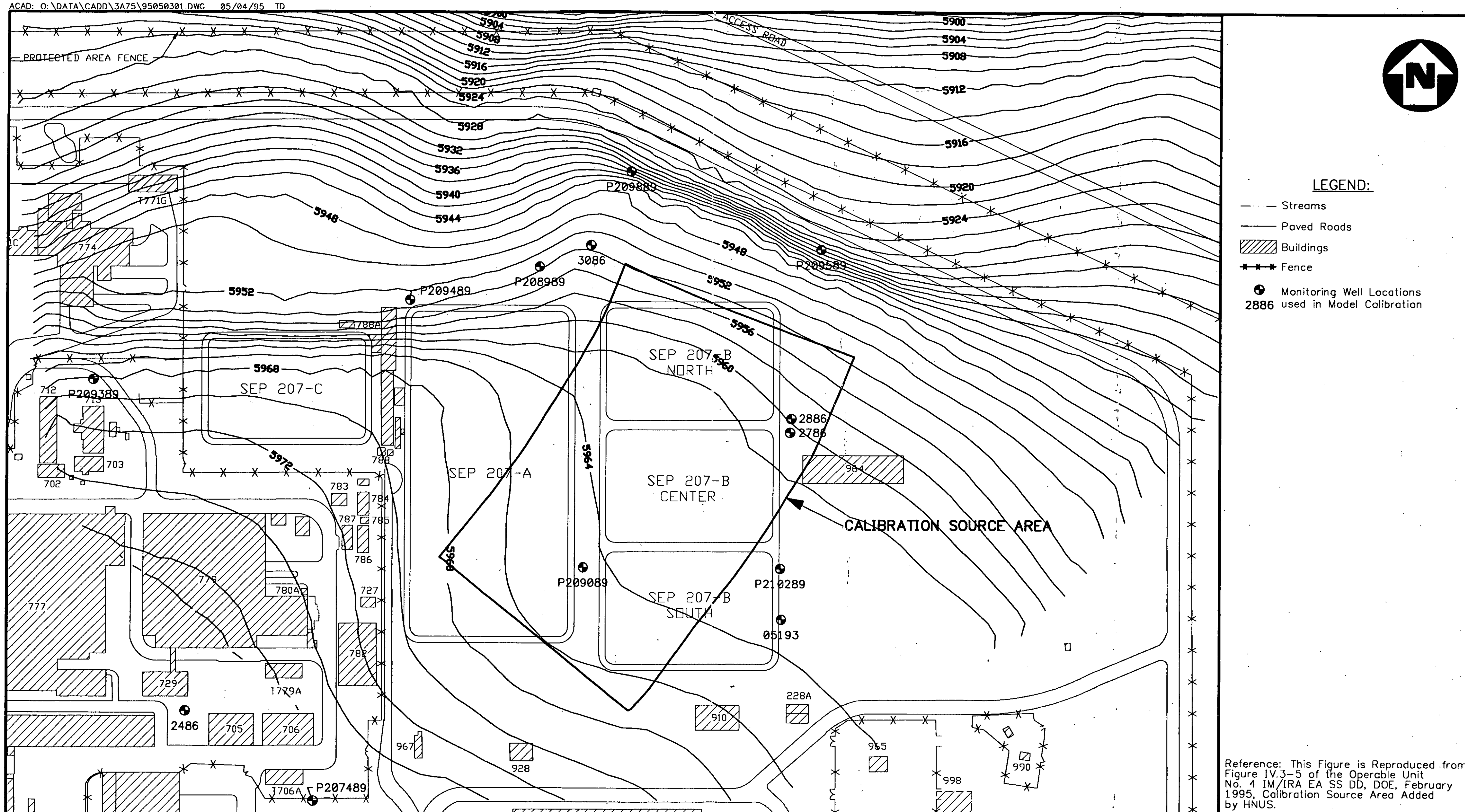
Mean value in simulation was 3,683.09



End of Assumptions

FIGURE B-46f SAMPLE MONTE CARLO SIMULATION OUTPUT

ACAD: O:\DATA\CADD\3A75\95050301.DWG 05/04/95 TD



MEAN SEASONAL HIGH
GROUNDWATER ELEVATION AND
CALIBRATION SOURCE AREA
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-4

Halliburton NUS CORPORATION

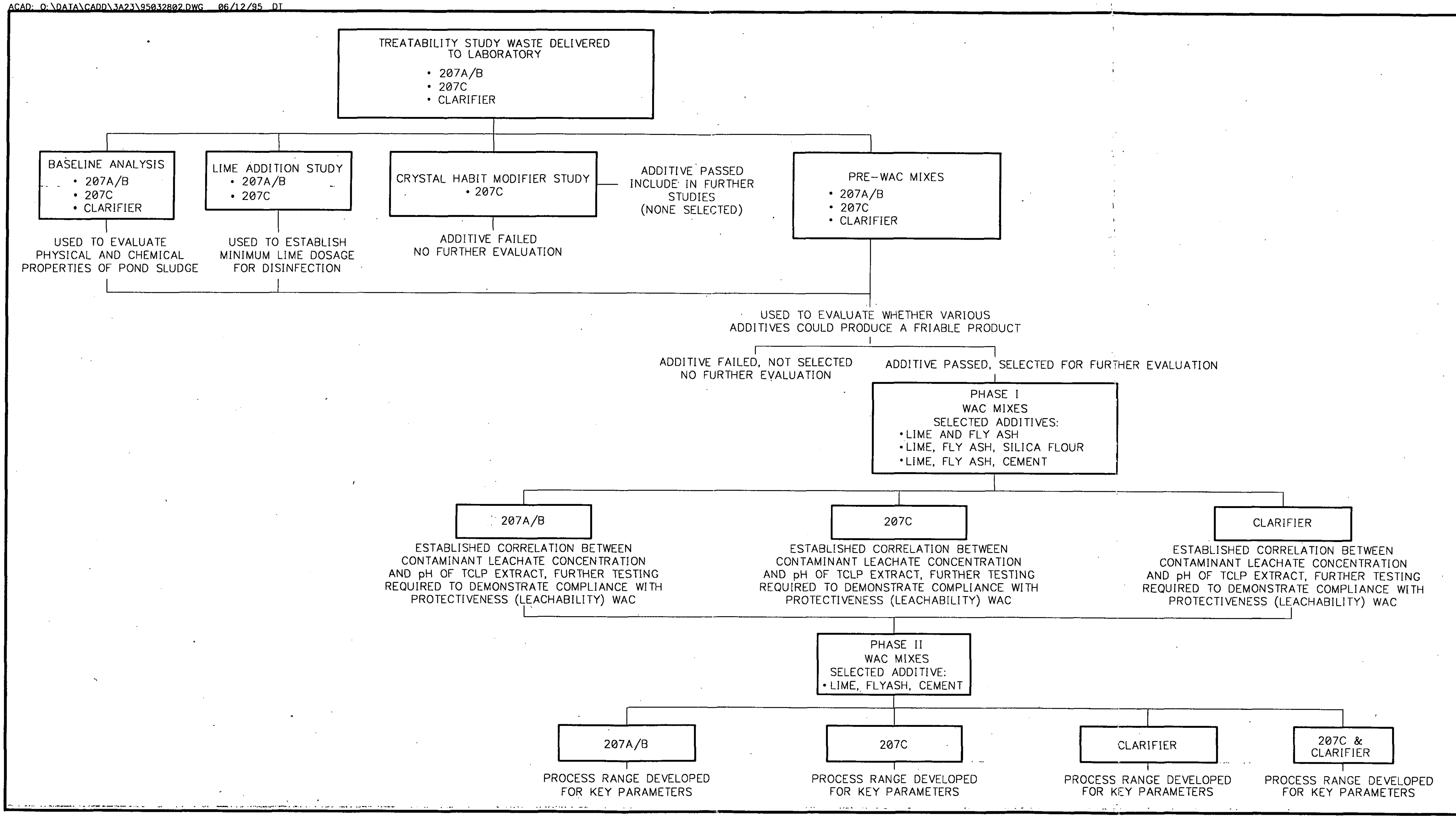


FIGURE 2-1

PONDSLUDGE TREATABILITY STUDY LOGIC DIAGRAM
ROCKY FLATS, COLORADO

Halliburton NUS CORPORATION